REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
1967

2. REPORT TYPE
Administrative Report; Open File Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Hydrology Training Manual Number 2: Computation of Basic Streamflow Records. Appendix 15.
Surface water investigations in Afghanistan: a summary of activities from 1952 to 1969.
United States Operations Mission to Afghanistan; International Cooperation Administration, Lashkar Gah, Afghanistan.

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Westfall, Arthur O.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Geological Survey (USGS)
12201 Sunrise Valley Drive
Reston, VA 20192, USA

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
HVA; ICA; USGS; USAID

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited

13. SUPPLEMENTARY NOTES
Appendix 15. Attachment- Pocket contains 13 items.

14. ABSTRACT
The purpose of this report is to summarize briefly the history of the Surface Water Research project since its inception in 1952, the work accomplished, and the problems encountered. In general, each topic is discussed under two periods of time: 1952-1963, when projects were confined to the Helmand River Valley and was entitled "Helmand Surface Water Investigations (306-12-021, 306-M-12-AD and 306-AC-12-AD5)," and 1963-1969 when activities were expanded to cover most of Afghanistan and title was changed to "Surface Water Research (306-11-190-002)".

Prepared by the United States Geological Survey in cooperation with the Water and Soil Survey Department, Ministry of Agriculture and Irrigation, Royal Government of Afghanistan under the auspices of the United States Agency for International Development.

15. SUBJECT TERMS
Afghanistan. Drainage. Flood control. Helmand River Project. HVA. Helmand Valley Authority. Hydrology. Hydropower. Irrigation. Lashkar Gah. Rainfall Runoff Calculations. Sediment. Stream-flow Data. Stream gaging stations. Stream measurements. Surface Water. Water supply.

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UU	UU	UU	UU	113	19b. TELEPHONE NUMBER *(Include area code)*

(200)

WR3 wsw appendix 15

Appendix (15)

HYDROLOGY

TRAINING MANUAL No. 2

COMPUTATION of BASIC STREAMFLOW RECORDS

MINISTRY OF AGRICULTURE

HYDROLOGY TRAINING MANUAL

Number 2 - Computation of Basic Streamflow Records

Prepared by the

United States Agency for International Development

Mission to Afghanistan

in cooperation with the

Water and Soils Survey Department

of the

Ministry of Agriculture

Royal Government of Afghanistan

Kabul

1967

CONTENTS

CONTENTS

ILLUSTRATIONS

CONTENTS

Computation of Basic
Streamflow Records
by
Arthur O. Westfall
U. S. Geological Survey

INTRODUCTION

This manual describes the methods and procedures for computing measurements of river stage and discharge and how to present the data in a logical and usable form. The computations require a fairly definite procedure to facilitate the work and reduce errors, and a standard format is used to facilitate comparison of sets of data between different areas or time periods. These instructions do not cover all irregularities and problems that will confront the technician; they cover only the basic elements. As the technician becomes adept at applying the principles in this manual he will be able to cope with more difficult problems as they occur.

The field and office work cannot be separated so that one group of technicians does nothing but field work and another group does only office work. To properly interpret the data in the office, the technician must know what kind of field conditions cause certain irregularities, and conversely, the technician in the field must understand what kind of data is needed for proper office interpretation.

This manual is composed of several parts: First, as part of the introduction, a section is included which digresses back to field operations. It cannot be stressed too strongly that all computations are based on the data obtained in the field and if this data is incomplete or incorrect, then all computations based on such data may be in error. In the second and third parts the methods for interpreting stage and discharge data are given. The fourth and fifth parts discuss methods where the stage and discharge data are brought together to establish the stage-discharge relationship for the station. In the sixth part, the presentation of the data in usable form is discussed. The seventh part discusses a method for detecting gross errors or for estimating missing or inaccurate records. The eighth part shows how to document the analysis of the data so that future investigations of the quality of the record will disclose exactly what the engineer was thinking as he analyzed the data. The ninth part discusses points in the analysis that should be checked by an experienced hydrologist to assure that no errors in logic or continuity have occurred. Part ten deals with general information that will help in the overall organization of the data or interpretation of the record. Part eleven shows the various forms developed to assist in the analyses and interpretations. In part twelve, an introduction to advanced hydrology is presented to show how the basic data can be further developed and used in engineering and hydraulic studies.

This manual was written by a U.S. Geological Survey hydrologist specifically for use by the Water and Soil Survey Department of the Ministry of Agriculture and Irrigation, Royal Government of Afghanistan. The methods described herein are largely those in current use by the U.S. Geological Survey in their domestic program. In some parts these methods were modified to meet Afghanistan conditions.

Gaging Station Procedure

All too often when a hydrographer visits a gaging station he fails to note items that are necessary for correct and complete computations of the stream flow record in the office. Without complete information it is difficult and often impossible to know what has occurred at the gage. Certain routine checks and proper note keeping must be done by the man in the field to assure that all information available is recorded so the technician computing the records can visualize the conditions in the field that existed during the hydrographer's visit.

The following steps, if done in order and as described, should result in obtaining complete and accurate information during most routine visits. The hydrographer should remember, however, that unusual conditions not covered by these instructions will often be met, and that there is no substitute for alertness, common sense, and reason. The hydrographer must never consider a visit to a gaging station as a routine mechanical operation because, unlike other types of measurements that can be repeated later if an error is suspected, the measurement of flowing water is a "once only" type of measurement. After the water has passed the gaging station, the conditions that existed as it flowed past will never be exactly duplicated again.

1. Before opening the instrument shelter or even touching the gage well or walkway the hydrographer should:
   a. Find the gage observer, inspect his notes, and question him as to any unusual occurrences

such as floods, periods of no flow, excessive regulation, channel changes, or clock stoppage that may have occurred. If a flood has occurred, find high water marks on or near the gage well and record the gage height of these marks on the current meter measurement notes. If periods of no flow have occurred, try to find out the dates and times and the reason (seasonal, regulation, work on channel, etc.). If channel changes have occurred because of work done by man, try to find out dates and times of such work. Be sure to record any information obtained on measurement notes or gaging station inspection form.

b. Look at condition of control and gage pool. If there is debris or vegetation growing on control or any visible change from previous visit, record this on measurement notes. <u>Do not remove debris or change anything on control at this time.</u>

c. Read outside staff gage to nearest 0.005 meter and record on measurement notes.

d. Make a quick visual inspection of the gage well and cableway noting anything unusual (cablecar in middle of cableway, bullet holes on staff gage or well, damage to cableway or well from high water, etc.).

2. Open recorder shelter very carefully and read tape gage before touching anything. Observe if tape gage is in float wheel splines. If not, do not disturb tape until after pen is read. If tape gage does not concur with staff gage, find reason (well silted, float or counter-weight hitting obstruction, recorder jammed, mud-dobber wasps built nest behind float wheel, etc.). The tape gage must read within plus or minus 0.010 meters of the staff gage or something is wrong. Find it.

3. Carefully open recorder cover and observe whether clock is running or stopped. Many times a stopped clock will restart spontaneously from the disturbance of the hydrographer on the walkway and while opening the shelter. If the chart trace has been flat since the clock first stopped, it may not be obvious that the clock was stopped. This is why so much care must be taken to avoid unnecessary disturbance when first approaching the gage.

4. Either from markings on the instrument shelf, by observation through the float tape holes in the shelf, or by observation through the inspection door, determine which

side of the float wheel the float is suspended from. Lift the pen arm, revolve the float wheel in the direction that raises the float, and make a mark with the recorder pen at least two full chart divisions above the trace line. Raise pen to locking position before allowing float wheel to resume normal position.

5. Release feed roll clutch located on lower right side of recorder by pulling to right (outward) and revolving away (clockwise) from you until chart paper loses its tension. Move chart about 15 cm. onto takeup roll until end of trace is at upper edge of writing platform.
6. Make notations on chart as shown on accompanying illustrations:
   a. Figure 1 illustrates the proper notes when the gage is functioning normally. The gage height scale is shown by the card on the inside of the recorder lid or by computing from the end of the trace.

      The DPI is a peak indicating device that is clipped onto the float side of the float tape. As the float rises, the DPI remains against the bottom of the instrument shelf and slides on the tape. As the stage recedes, the DPI remains fixed to the tape at the highest point of the peak stage. This reading

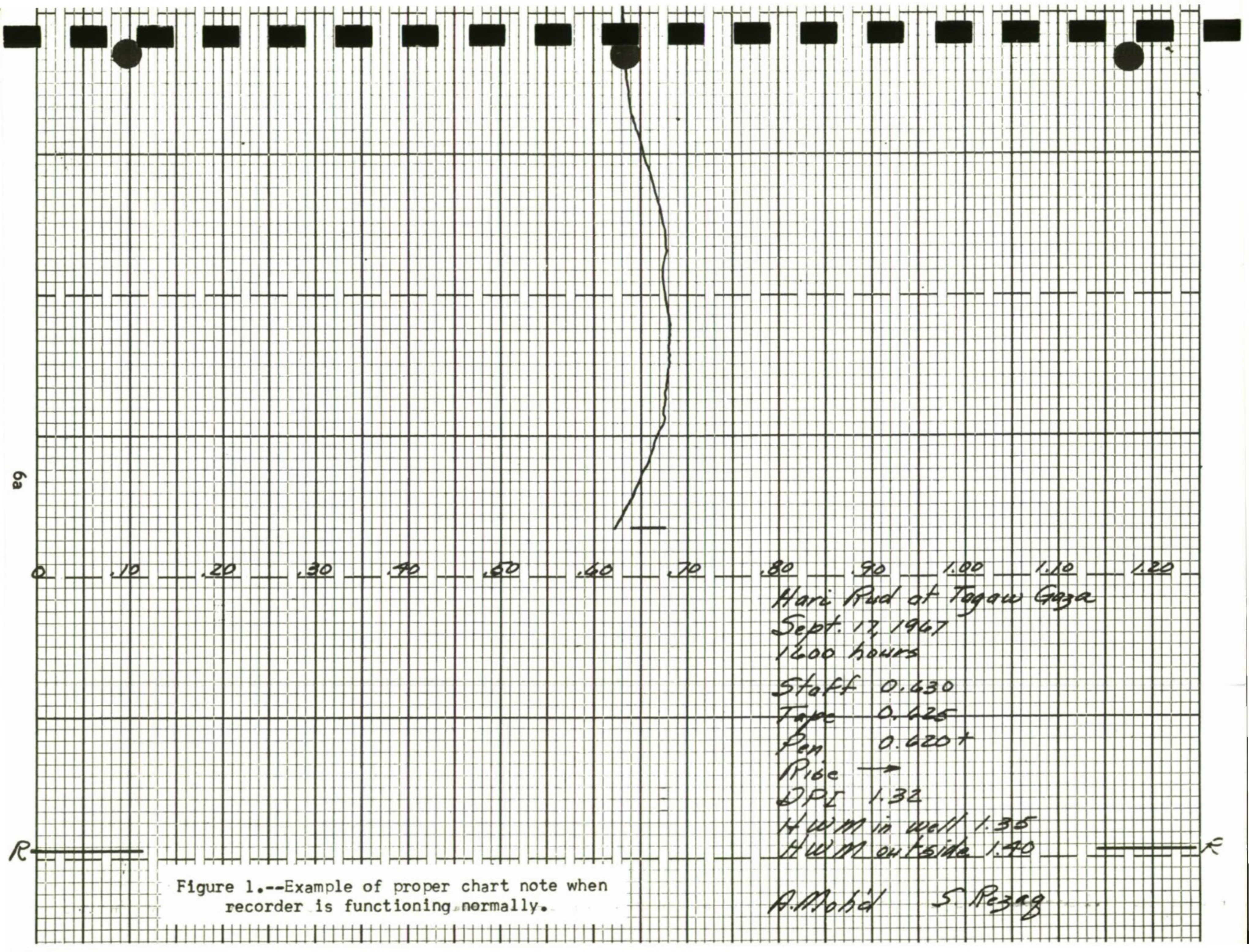


Figure 1.--Example of proper chart note when recorder is functioning normally.

(taken from the top of the DPI) plus the distance from the bottom of the instrument shelf to the pointer on the tape index, is the peak stage that has occurred since the last time the DPI was reset and should correspond to the peak stage reading of the chart trace.

The "Rise" notation indicates the direction of pen travel when the float wheel is revolved in the direction that raises the float. This notation is especially important during times of high water or diurnal fluctuations when the pen trace may have gone through several reversals.

The reversal marks at each side of the chart are made by removing the float tape from the float wheel, revolving the float until the pen is within two or three major chart divisions of the side, lowering the pen to the chart, and again revolving the float wheel until the pen has gone through the reversal. Repeat this procedure at the other side of the chart. Return pen to normal position and reengage float tape in float wheel splines. Make sure pen is moving in proper direction when float is raised.

During periods of low water when no peaks have occurred since the previous visit, the HWM notation can be omitted. If there has been a peak since the previous visit, the HWM notation is made and the high water marks, both inside the well and outside, are destroyed or rubbed off to avoid confusion at a later visit.

b. Figure 2 illustrates the proper notes when the clock has stopped and the pen is in reverse.

From the chart trace and the direction of pen travel when the float is raised, you can tell that the stage has risen through a pen reversal and stayed in that range during the time the clock has been stopped. You cannot tell how many times the pen has traversed the same line while the clock was stopped nor whether the river is receding or rising at the time of your visit. You can tell only that during the period the clock was stopped the range in stage was from 1.750- meters to 2.005 meters. Comparison with the gage observer's readings will establish the date of the peak or peaks and the recession.

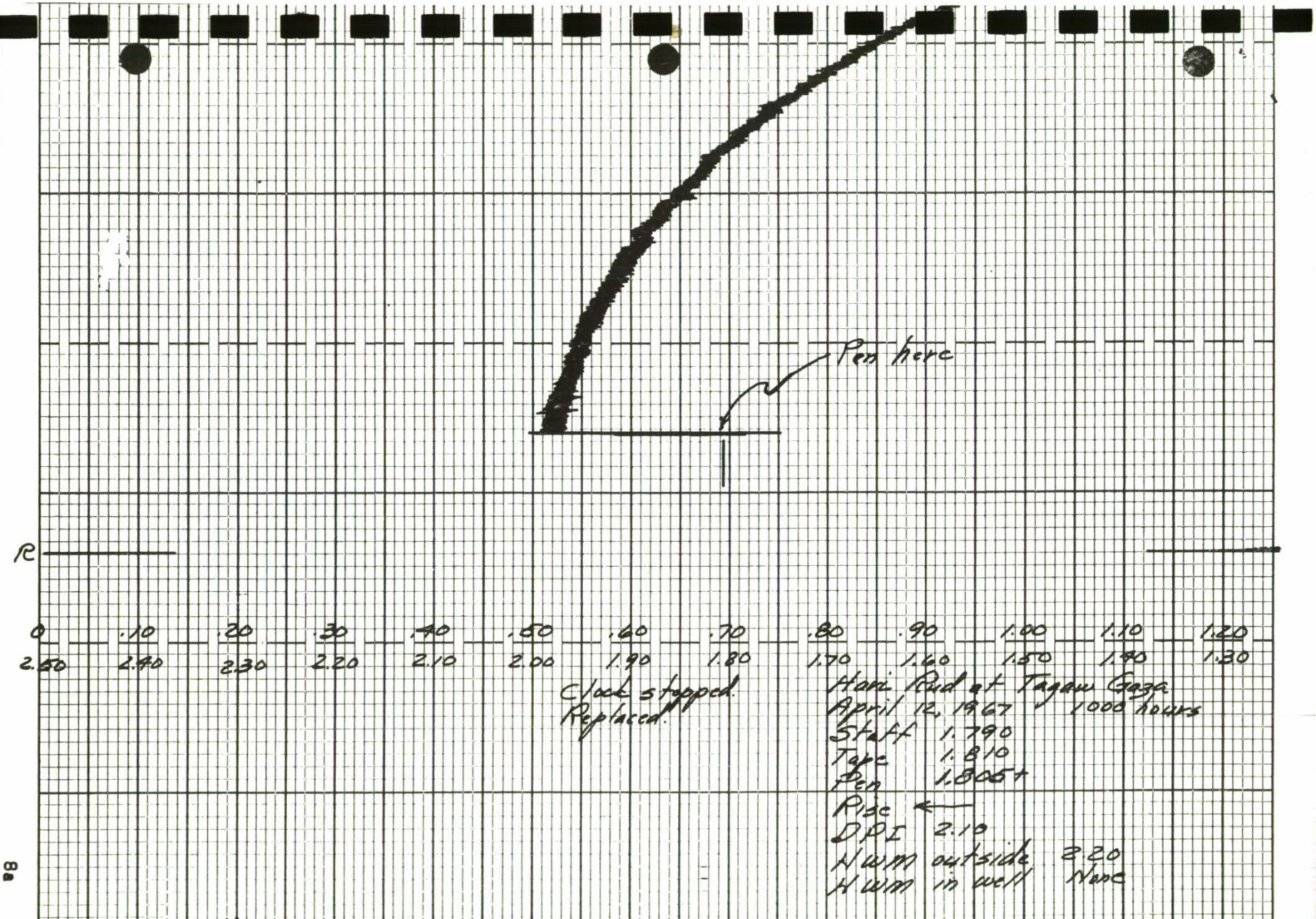


Figure 2.--Example of proper chart note when clock has stopped and pen is in reverse.

Sometimes during a rapid rise in stage or excessive surge, the float tape may come out of the splines on the float wheel. Always compare the ending gage-height scale with the beginning gage-height scale when you remove the chart. If they are not in agreement (taking reversals into consideration), scan the trace line carefully for the entire period to see if there is any evidence of the tape gage coming out of the float wheel splines. If evidence is found, change float wheel splines to adjacent holes in float tape until ending gage-height scale agrees with starting scale and pen is reading within 0.005 meters of tape gage.

If the beginning and ending gage-height scales cannot be brought into agreement by the above procedure, check the float wheel tightening screws and the float wheel shaft nut. If these are found loose (one screw has a left-hand thread) then the float wheel has probably been slipping on the shaft and a rise or fall of the float has not produced a corresponding rise or fall of the pen. Scan the chart trace for unnatural flat spots; this is usually indicative of a loose float wheel. Usually nothing can be done to reconstruct the true chart trace. However, if the float wheel is alternately slipping and holding, then it is possible to reconstruct the chart trace by using the DPI or HWM readings as the maximum and using the trace to shape the accession and recession curves.

The cause of the clock stoppage should be investigated. It is not necessary to replace the clock if it has stopped because of the following reasons:

Clock weight on bottom of well.

Clock weight cable too short.

Clock weight resting on obstruction.

Clock weight cable binding on drum.

Clock weight spring hung on instrument shelf.

Abnormally cold temperatures.

See section 10.600 for instructions on correcting these conditions. All other causes require replacement of clock and/or recorder.

c. Figure 3 illustrates the proper notes when the well is silted up or the intakes are plugged. The well should be cleaned or the intakes opened and the tape and pen readings again marked on the chart when normal conditions have been reestablished.

Other causes will show a similar trace pattern to that shown in Figure 3:

Float, float tape, or counterweight hitting obstruction.

Well frozen.

Float tape off float wheel.

Recorder jammed (if near reversal point).

Float wheel tightening screws loose.

Mud-dobber wasps have built nest between float wheel and recorder case.

See section 10.500 for instructions on correcting these conditions.

7. Remove chart by turning takeup roll until last of notes have passed upper edge of writing platform; cut with knife or fingernail along upper edge of writing platform and reroll chart by hand, inspecting trace line until chart is rerolled. Remove takeup roll clip and place rubber band around used chart roll.

8. Wind clock carefully with the crank using free hand to guide cable onto drum evenly. Do not wind clock cable so far that clock weight spring contacts instrument shelf or, on negator spring driven recorders, past the red mark on the spring. Remove crank and replace dust cap.

9. If new supply roll is not needed clip end of chart roll on takeup roller making sure chart paper is butted against roller collar on left side. Take 3 or 4 full turns of paper onto takeup roller making sure paper is running straight.

10. Inspect chart roll to see how many days of record are left on the supply roll. If you observe a diagonal printed line on the roll, count the number of heavy lines (centimeters) from the left margin to the diagonal line and multiply by 8. The product equals the number of days supply remaining on the roll. If the number of days of chart remaining will not be adequate until the next visit, install a new supply roll.

    A new supply roll is installed by removing the writing platform and lifting the old supply roll and shaft out. Unscrew the knurled collar on the shaft end and remove old roll from shaft. Slide new roll on shaft so that the roll end with the core protruding is to your right or the knurled collar end of the shaft.

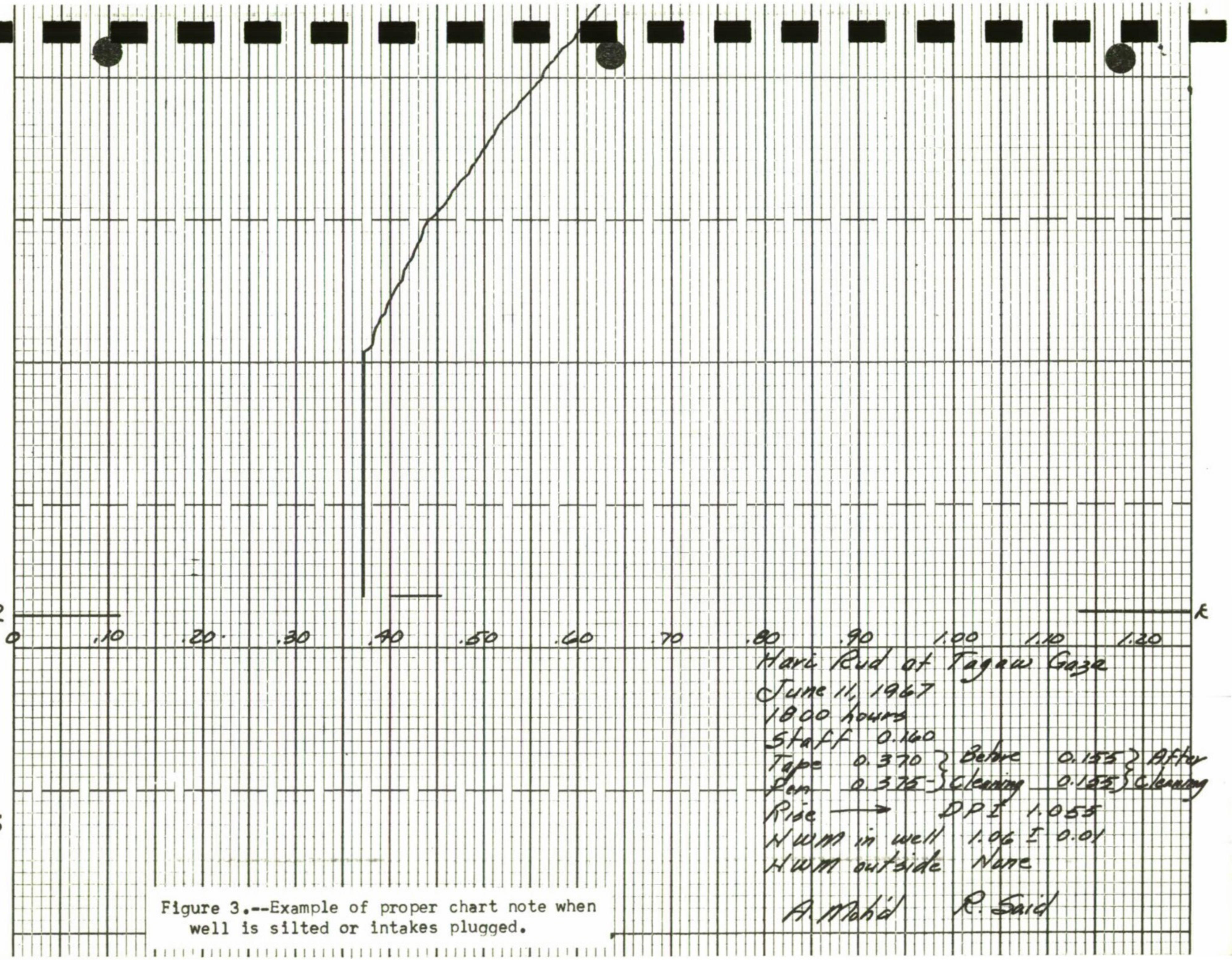


Figure 3.--Example of proper chart note when well is silted or intakes plugged.

Screw knurled collar snug against core of supply roll. Replace roll and shaft into slots and thread paper between idler roller and the small tension rollers. Replace writing platform and proceed as in paragraph 9 above.

11. Mark beginning note on chart as shown in Figure 4. In addition to the notes shown, add any other information that may be appropriate such as well cleaned, levels run, staff gage repaired, PZF (point of zero flow), etc. If in doubt as to whether certain information is to be put on the chart or on some other form such as measurement notes or level notes, put it on both. Too often vital information is lost because it was put on scratch paper and then forgotten or filed and never seen again.

A few adjustments may be necessary at this point to bring all gages to the same reading and to center the reversal points:

a. To center the reversal points:

Remove float tape from float wheel; move pen carriage to side by revolving float wheel; lower pen to chart and make mark about two major divisions long as the pen moves through the reversal point; raise pen, move carriage to other side and repeat marking. If reversals are not centered, loosen slide bar screw on pen carriage and move pen in appropriate direction; advance chart paper slightly and repeat markings. Continue this process until reversals are centered.

Atmospheric conditions cause the chart paper to contract or expand and it may not always be possible to match the reversal points to the chart margins. If this occurs, adjust the reversal points so that they are the same distance from both margins.

Never adjust reversal points by twisting pen capillary tube in lucite reservoir. You might disturb angle at which pen contacts chart resulting in loss of record if the pen stops inking.

b. To adjust pen reading to tape gage reading: Loosen float wheel tightening screws; hold float wheel with one hand while turning the float wheel shaft with the other hand; when pen reaches proper reading, tighten float wheel screws (be sure to turn screws in correct direction. One screw has right hand thread, the other a left hand thread. Arrows engraved on the screw head point in the correct direction to tighten screws).

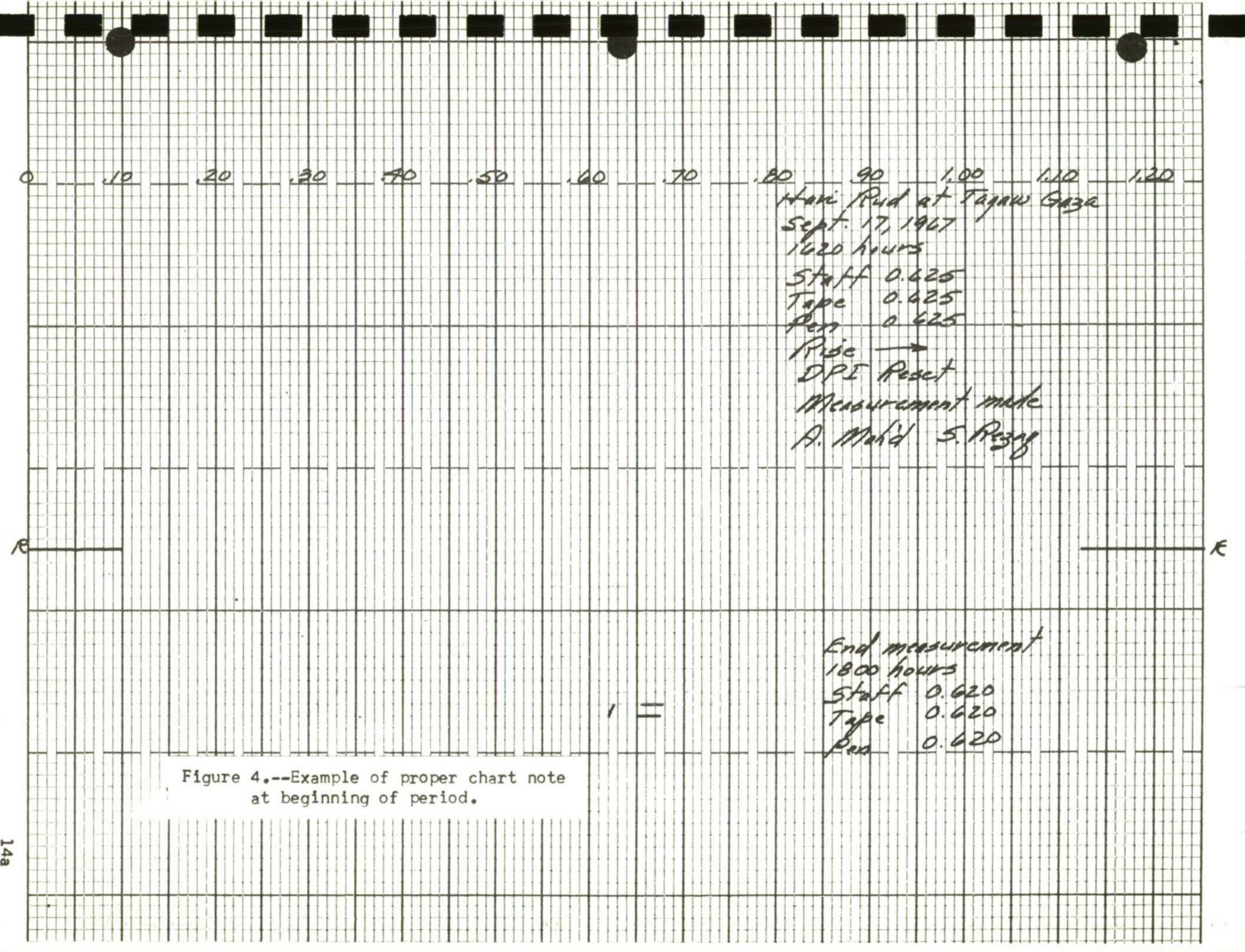


Figure 4.--Example of proper chart note at beginning of period.

c. To adjust tape gage reading to staff gage reading[1/] loosen index pointer screw and move to correct reading; tighten screw.

12. Engage feed roll clutch by pushing in (to left).

13. Make final visual inspection to assure clock has been wound and is running (observe movement of balance wheel through observation glass), pen is marking, slide bar screw is tight, float wheel screws and shaft nut are tight, feed roll clutch is in, float tape is in float wheel splines, and DPI has been reset. Close and latch recorder lid. Close recorder shelter door or cover.

14. Make current meter measurement according to appropriate method as described in HYDROLOGY TRAINING MANUAL, No. 1 - Basic Streamgaging. Compute measurement. If it is more than 5 percent away from current rating, or does not line up with the previous measurement, repeat measurement.

[1/] In Afghanistan, most gaging stations have no staff gage inside the stilling well. Therefore, the outside staff gage is the base gage and all other gages are set to read the same as the outside staff gage. The hydrographer must be especially careful to inspect the staff gage for damage at each visit. If evidence of damage exists, levels must be run to the RMs (reference marks) to assure that the outside staff gage is reading correctly. If the staff gage is found in error, the tape gage then becomes the base gage until the staff gage is repaired.

Assuming the staff gage to be correct, the procedure would be to set the tape gage to the staff gage, and then the pen to the tape gage.

15. Return to recorder and enter "End measurement" notes as shown in Figure 4. Again make visual inspection as stated in step 13 above.

16. Remove debris from control if possible. If gage pool is small and will reach equilibrium within a short time after cleaning control, wait and record gage readings on chart and measurement notes when flow is again stable. If gage pool is large and will take several hours to reach equilibrium after removal of debris, go on to next station and return later to record stabilized gage readings if possible. If it is not possible to return later, the gage reading can be obtained from the chart trace after the next routine visit.

Some recorders are equipped with an auxiliary pencil. This pencil is a safeguard against loss of record in case the pen does not function properly. The pencil yoke clips onto the pen carriage yoke and lags the pen by a constant number of hours and shows a constant lesser gage height than the pen. It is not necessary to note the pencil readings if the pen is functioning normally. If the pen is not marking then note the pencil reading just the same as you would have for the pen reading. The time and gage height lag corrections can be obtained from the starting trace for that period of record.

The data the hydrographer should bring back to the office after a routine visit are the recorder chart, current meter measurement notes, level notes (if levels are run), observer's notes through the end of the previous month, and station inspection form (the station inspection form is usually filled out only once a year routinely, or whenever any damage has been discovered at the station).

The hydrographer should also see that the observer has an adequate supply of observer's notes; and if the observer has been collecting sediment samples, to bring those samples back to the laboratory.

GAGE-HEIGHT RECORDS

In the computation of streamflow records for a gaging station, two parameters measured in the field are basic to all computations: The stage of the river (or gage height as it is more properly called when used in reference to a gaging station), and the discharge.

Stage or gage height is the elevation of the water surface in reference to an arbitrary datum. It is measured by means of permanently set staff gages, or by instruments such as tape or wire weight gages that measure the distance from the water surface to an index point that is set to an arbitrary datum.

A gaging station can be either a recording or non-recording station. At non-recording stations, the gage is generally a staff gage. At recording stations, the gage is generally a staff gage supplemented by a float-tape gage to which is attached a recording device to measure changes of the float-tape gage. This is called an automatic water-stage recorder.

In Afghanistan, most of the automatic water-stage recorders are Stevens model A35 recorders furnished as part of the USAID program. There are also Ott recorders furnished by the West German Hydrologic Mission and the United Nations. The principle behind the operation of all recorders used in Afghanistan is the same (that is, gage height is measured in one direction and time in another direction), and discussion in this manual will be confined to the Stevens A35 recorder.

A complete description of the various type gages of American manufacture is given in part 4 of HYDROLOGY TRAINING MANUAL, No. 1 - Basic Streamgaging. Also sections 10.500 and 10.600 of this manual contain material referring to automatic water-stage recorders.

Recorder Chart

The Stevens A35 recorder uses a strip chart to record the changes in stage and time. This chart is a long continuous roll and under most conditions of use in Afghanistan, will last for 2 years before a new roll needs to be installed. Because of this feature the recorders can be run for several months, the limiting factor being the available length of fall of the clock weight.

The chart is divided into 25 major divisions across the chart: the distance between divisions represents 0.05 meters change in elevation of the water surface. Each major division has 5 minor divisions: the distance between each minor division represents 0.01 meter change in elevation. Down the length of the chart are major divisions shown by heavy solid and heavy dashed lines: the distance between any two major divisions represents 24 hours. Between the major divisions are 12 minor divisions: the distance between each minor division represents 2 hours. These scales can be changed if desired, but for most purposes the above scales are suitable.

Inspection notes.--Inspection notes appear on the recorder chart on the days that an engineer has visited the station for some purpose. This means there are inspection notes at the beginning and end of each chart section and there may be notes at any intermediate point (see figures 1 to 4, section 1.100). The technician should examine these notes carefully for completeness and accuracy. Check the notation for pen gage height and time against that shown by the trace. If any discrepancy appears check against the measurement notes (if available) or with the hydrographer who made the inspection notes. Any discrepancy or omission should be brought to the attention of the hydrographer so that correct or adequate notes will be made by him on future visits.

Time corrections.--Recorder malfunction or climatic conditions can introduce a difference between the recorder pen time and correct time, and between the pen gage height and base gage height. In most recorders, it is impossible to regulate the clock to keep accurate time under all conditions. Also, the chart paper may not run straight or damp weather may cause the paper to expand. These conditions are not considered errors, but they do require corrections or adjustments to the relation of the trace line to the chart graph.

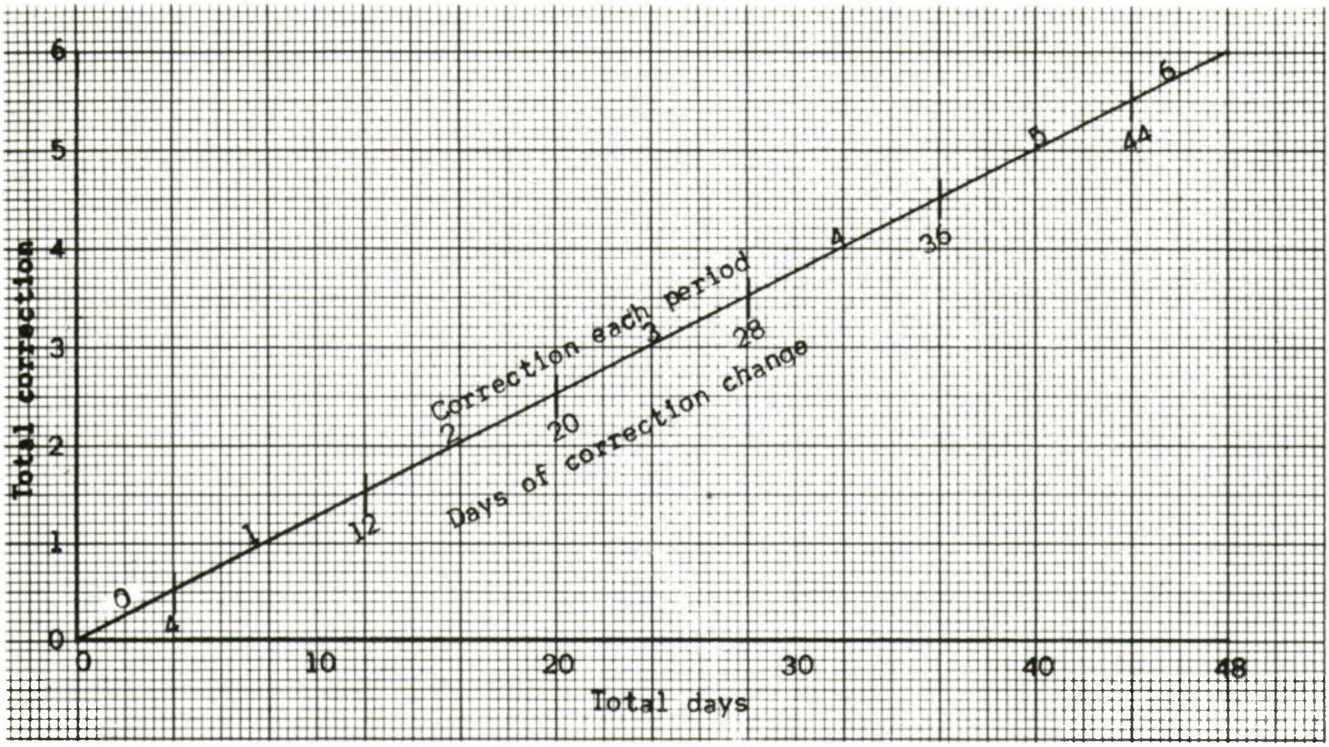
A clock is the speed regulating device for the recorder. When it runs fast or slow the rate at which the recorder chart moves under the pen will also be fast or slow. Unless evidence to the contrary is found, it is assumed that a clock running fast or slow does so at a constant rate. Therefore, a clock that runs (say) 6 minutes slow each day will be an hour slow at the end of 10 days of operation, and if an engineer visits the station at the end of 60 days he will find the pen time shows 6 hours slower than correct time at the end of the period.

Corrections are made to the nearest hour. In the above example, the error was less than one-half hour during the first five days and no correction is needed; from the sixth to the fifteenth day the clock was progressively slower from one-half hour to one and one-half hours and the correction is one hour; from the sixteenth to the twenty-fifth day the clock will be from one and one-half hours to two and one-half hours slow and the correction is two hours. The correction increases by one hour every ten days with the maximum correction occurring during the final five days.

Unfortunately, visits are not always made at such convenient intervals as 30 or 60 days. Usually, visits occur at odd times. Let's assume that 48 days have elapsed between visits and the clock was 6 hours slow at the end of the period. Then 48/6 = 8 and the clock will run an hour slow every eight days. Using the same procedure as the preceding example the correction would be:

Day	Correction (hours)
0-4	0
5-12	1
13-20	2
21-28	3
29-36	4
37-44	5
45-48	6

Time corrections can also be computed graphically and this is perhaps the best method for inexperienced technicians. Using ordinary graph paper or a vacant spot on the recorder graph being computed, mark the total days on the abscissa and the total correction on alternate lines on the ordinate. Draw a straight line from zero days and zero correction to the intersection of the last day and maximum correction. Where the line crosses the $\frac{1}{2}$, $1\frac{1}{2}$, $2\frac{1}{2}$, etc., total correction points are the days where the correction changes. This method is illustrated in the following graph.



In practice, it is customary to use calendar dates instead of total days. Thus, the days of correction change are given as the actual date appearing on the recorder chart.

Time changes are shown on the recorder graph by moving the midnight line for each day in the proper direction. For example, assume a recorder runs 4 hours fast in 20 days. Figure 5 shows the movement of the midnight line under this condition.

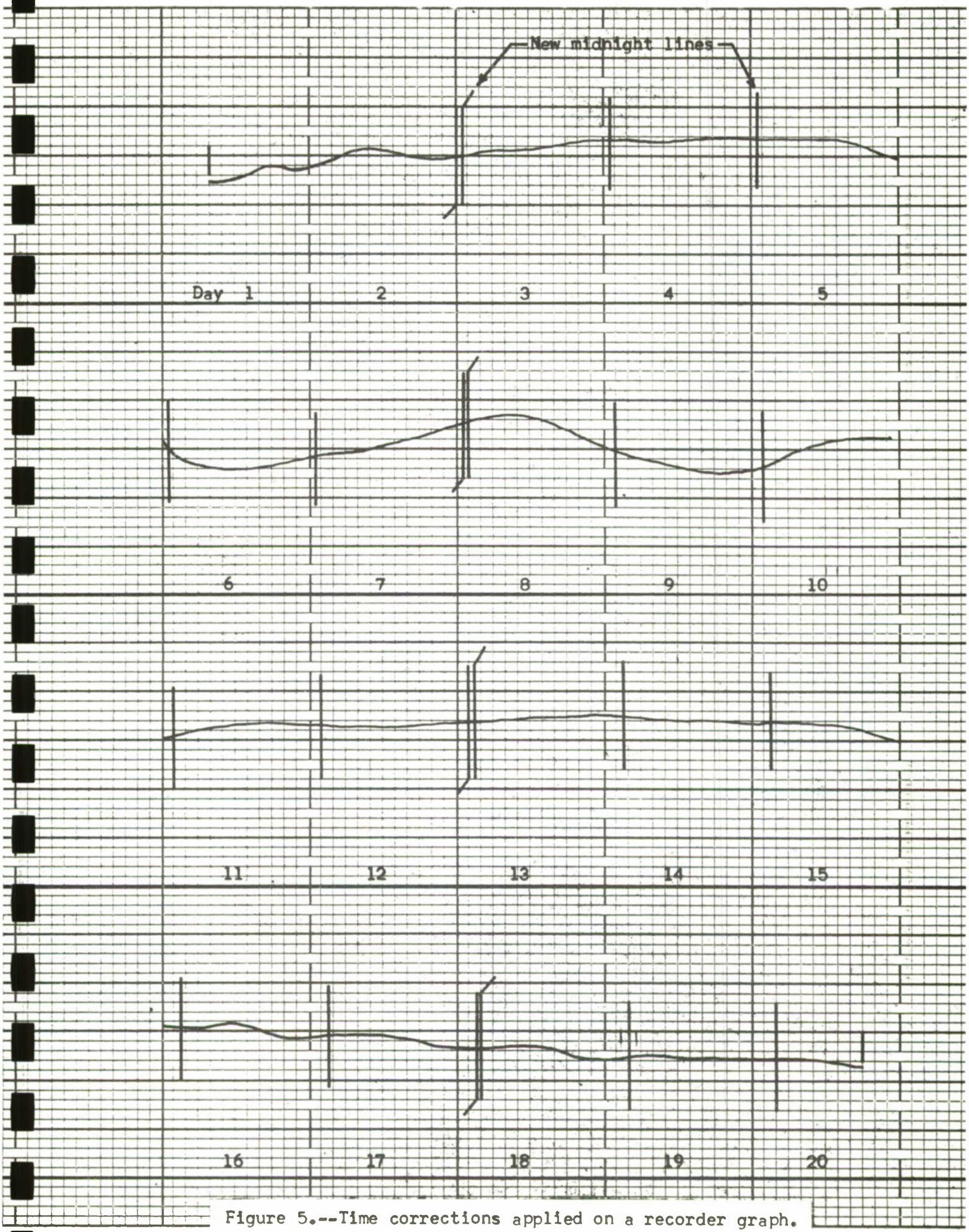


Figure 5.--Time corrections applied on a recorder graph.

<u>Gage-height corrections.</u>--Corrections for the difference between pen gage height and the base gage height are made in exactly the same way as time corrections. For example, assume that the pen reading was +0.06 meters of the base gage reading at the end of the 48 day period. Then 48/6 = 8 shows that the pen reading gradually increased in error by 0.01 meter every 8 days. Corrections are made to the nearest 0.01 meter. Therefore, by applying the same principle used for time corrections the gage-height correction would be:

Day	Correction (meters)
0-4	0
5-12	-0.01
13-20	-0.02
21-28	-0.03
29-36	-0.04
37-44	-0.05
45-48	-0.06

The correction is applied in the opposite direction from the error in pen reading.

Corrections to pen gage-height readings can also be made graphically. The principle is exactly the same as shown for time corrections; but again, remember that the correction is applied in the opposite direction from the error.

Another type of adjustment that may be necessary to the pen gage-height reading are those caused by reversal errors. These fall into two categories:

1. Corrections for errors in setting reversal points. These are the simplest of the reversal errors to adjust. If the reversal occurs above the base lines then add double the

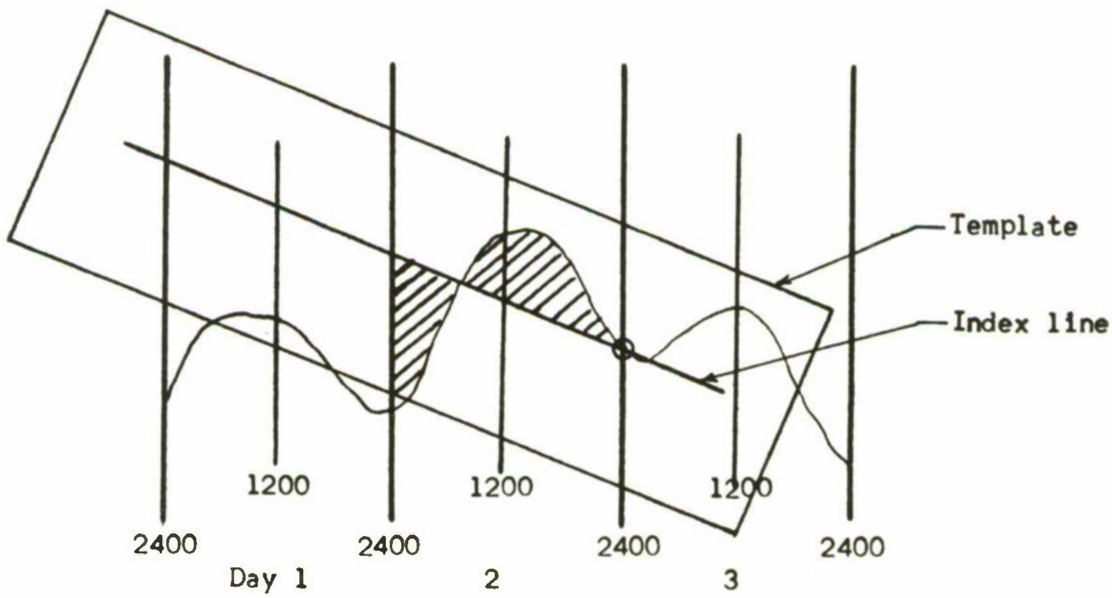
error to the gage height while the pen is in reverse. If the reversal occurs below the base lines then subtract double the error from the gage height while the pen is in reverse. No adjustment is necessary while the pen is in direct drive.

2. Correction for skewed paper. If the chart paper runs crooked an accumulative error occurs in the pen reading and also in the reversal points. This is generally the cause of the difference in pen and base gage readings. If no reversal of pen travel has occurred, the pen reading is adjusted by proration for time just as described for time and gage-height corrections. If reversals have occurred, they are adjusted by proration for time and also for position in relation to the base line as described above.

Occasionally, atmospheric conditions will cause the paper to expand or contract. If the reversal check shows the reversal points to be centered equally in relation to the base lines (either inside or outside the lines) no adjustment is necessary.

The corrections are written on the recorder graph for the days where corrections are needed. This correction is then added to or subtracted from the computed gage height to give the corrected gage height.

Daily gage heights.--In general, a mean gage height is computed for each day of the water year. This gage height is obtained by averaging all gage heights occurring within a 24-hour period from midnight to midnight. Since the recorder chart trace is composed of an infinite number of points this is accomplished by a method that balances the areas of chart above and below an index line. For this purpose a template is used. This template is rectangular in shape and has an index line etched along the major axis. For convenience of use, a small hole is drilled near one end of the index line. By holding the template with a pencil point so that the hole in the index line is at the intersection of the pen trace and the midnight line (2400 hours), the template can be revolved about the pencil point until the position of the line is such that the chart areas above and below the index line are balanced. The cross-hatching in the illustration below shows how the template is used to balance the areas.



The mean gage height for the day is at the intersection of the index line and the noon line (1200 hours).

During periods of rapidly changing stage a daily mean gage height is not computed. Heavy precipitation or rising temperatures may cause a large change in stage and discharge, or upstream regulation may cause sudden surges or cessations of flow. During these periods of rapid change a daily mean gage height really has no meaning; and also, if the mean gage height were used to obtain the mean discharge from a rating curve (see section 4.000) the discharge would be too low because of the curvature in the stage-discharge relationship.

Periods of rapidly changing stage are computed by subdividing the day into one or two-hour periods and obtaining the gage height at each interval. A discharge is then applied to each gage height and the average discharge computed by summation, giving normal weight to the discharges at each midnight point (0000 hours and 2400 hours) and double weight to the intermediate points, then dividing by the sum of the weighting factors (24 for 2-hour subdivision, 48 for 1-hour). The following table illustrates this method:

Time	Gage height	Discharge	Weight	Total
0000	0.920	45.7	1	45.7
0200	1.050	60.2	2	120.4
0400	1.125	69.0	2	138.0
0600	1.850	180.0	2	360.0
0800	2.280	268.0	2	536.0
1000	1.950	200.0	2	400.0
1200	1.750	162.0	2	324.0
1400	1.690	151.0	2	302.0
1600	1.560	130.0	2	260.0
1800	1.430	110.0	2	220.0

Time	Gage height	Discharge	Weight	Total
2000	1.300	91.0	2	182.0
2200	1.230	81.9	2	163.8
2400	1.175	75.0	1	75.0
			24	3,126.9

Mean discharge = 3,126.9/24 = 130.3 cubic meters per second.

A mean discharge is never obtained from averaging the gage heights and obtaining the discharge for that mean gage height. This will result in a discharge less than the true discharge as computed by the above method. For example, the mean of the gage heights listed in the above table is 1.485 meters. The corresponding discharge at this gage height is 117.5 cubic meters per second as compared to 130.3 obtained by the correct method - an error of almost 10 percent.

The data for the above examples were taken from a synthetic record that will be used for illustration throughout this manual.

Incomplete or inaccurate record.--Recorder or gage well malfunctions, or peculiarities in the hydraulic characteristics of the channel or gage well, can cause the recorder to fail to register the gage height or to register it erroneously. The causes of this are discussed in general in section 1.100, and in detail in section 10.500 and 10.600. Depending on the cause and what information is available to replace or supplement the pen gage-height readings, the incomplete or inaccurate record can be classified into one of the following:

1. No record.
2. Doubtful record.
3. Reconstructed record.
4. Ice-affected record.

No gage-height record is the result of the failure of the recorder to mark a normal trace line in either or both directions; that is, for time (clock stopped) or gage height (well silted, float hung up, etc.). When the clock is stopped, the recorder will still register gage height but all fluctuations will be recorded on a single line. This means, of course, that the range of stage occurring during the period of clock stoppage will be recorded, but intermediate fluctuations will not be shown nor will the time of occurrence of the extremes be known.

The recorded range in stage can be used as a basis for estimating daily discharges during the period concerned. By use of supplementary data, most notably gagemen's notes (see section 2.200) and comparison with records of nearby stations, a fair idea can be developed of the time that extremes and fluctuations occurred. Note that the estimates are for discharge, not gage height; gage heights are never estimated.

When the recorder marks time correctly but it is obvious the gage height is not being recorded, no range in stage can be obtained. Again, the gagemen's notes and comparison with nearby stations can be used to estimate the discharge. Also, these can be supplemented by use of a peak indicator (see section 1.100) or by defining high water marks at or near the gage well. The latter two will at least establish the maximum stage reached so that over-estimates of discharge can be avoided.

In the cases where the recorder doesn't function at all for either time or gage height, you must depend solely on gagemen's notes, high water marks, and comparison with nearby stations for estimating discharges. In most instances, the cause is failure of the pen to mark because of negligence in filling the ink reservoir or failure to make sure the pen is in the proper position. Both of these are inexcusable and show extremely poor work on the technicians' part.

Occasionally, because of malfunctions of the recorder (usually a slipping float wheel or float tape out of the splines) the pen gage height will not agree with the gagemen's notes, peak indicators, and high water marks; or a hydrographic comparison with records at nearby stations will reveal a gross difference during a certain period. Inspection of the chart trace may or may not indicate where a malfunction might have begun, or it may be evident that a malfunction has occurred and the trace is in error but the magnitude of the error cannot be defined. This can be classified as doubtful or fragmentary gage-height record, depending on whether it is felt the record is nearly correct but some doubt exists, or whether there is enough record available, supplemented by other data, to indicate closely the correct gage height. In cases where more than reasonable doubt exists or the record cannot be reconstructed reasonably well from a fragmentary trace, the record is completely disregarded and treated as no gage-height record.

Some gaging stations are affected by ice during the winter. If the water in the gage well freezes, the action of the recorder float is stopped. If ice forms on the control the stage-discharge relation is affected. If the gage pool freezes over (but not necessarily the control or well) the velocity of approach to the control and the hydraulic gradient can be affected. All of these result in either no stage-discharge relation or a change in stage-discharge relation and the discharge must be estimated during these periods.

Frequent discharge measurements during periods of ice affect is the best method of estimating discharge. This, supplemented by comparison with records for a nearby ice-free station will give reasonable estimates of discharge. Except in cases where the gage well is frozen the gage heights are computed exactly as though no ice affect were present, but these gage heights are not used to obtain the discharge. When the gage well is frozen the record is treated the same as no gage height record.

<u>Gage height of zero flow.</u>--The gage height or point of zero flow is defined as the gage height at which water ceases to flow over the control. This point should be measured in the field every time the stage is low enough or, if the control is stable bedrock, at least twice a year.

From the discharge notes the point of zero flow can be located on the recorder chart and no gage heights are computed for points below this. Occasionally, upstream regulation or diurnal flows may result in discharge for only part of a day. No mean gage heights are computed for these days. The days are subdivided and the discharge computed for the flow period. This is then averaged with no flow period to give the daily mean discharge.

Staff Gage Readings

Practically all of the gaging stations in Afghanistan have a gageman whose job is to take staff gage readings twice a day or oftener during periods of rapidly changing stage. These readings are used to verify or supplement the recorder chart readings on recording gages, or for computation of the daily mean gage heights at non-recording stations.

Generally, these readings are taken at 0800 and 1600 hours, and when the flow is steady a simple averaging of these readings can be used for the daily mean gage height. During periods of rapidly changing stage such as a storm period or diurnal fluctuation, a simple averaging of two or more readings may give an erroneous mean gage height because a peak flow could have occurred between readings. During these periods, the observer's readings should be plotted on a length of chart paper, and, guided by the timing of peaks or diurnals from a nearby station, a synthetic trace is drawn. The daily mean gage heights are computed from the synthetic trace exactly the same as a recorded trace (see section 2.140) including those days requiring subdivision.

DISCHARGE RECORDS

Discharge is the second of the two parameters measured in the field that are basic to all computations of streamflow. The term "discharge" is very comprehensive and can be used to describe any type of outflow whether in a stream, canal, or pipe. Other terms are used to distinguish flow from a drainage basin: Yield, the total water runout including surface flow and underground flow; runoff, the part of the water yield that appears as surface flow; streamflow, the actual flow in streams or rivers whether regulated or not. All of the above terms represent water and the dissolved and suspended matter in it.

In the computation of streamflow records, the term "discharge" is used in all cases regardless of whether or not the data is adjusted for upstream storage. Discharge can be expressed in terms of rate of flow or as total volume. In Afghanistan, flow rate is expressed in cubic meters per second (cumecs), and total volume in million cubic meters. Some of the older records, notably those of the Helmand Valley, express flow rates in cubic feet per second (cfs) and total volume in acre-feet. Other units are used in more advanced computations, but the above terms are those used in the computation of basic streamflow records.

Measurement Notes

The methods of making measurements of discharge are given in part 5 of HYDROLOGY TRAINING MANUAL, No. 1 - Basic Streamgaging. The data obtained during a discharge measurement are recorded on a measurement note form. This form contains not only data pertaining to discharge and gage height, but also information that will allow the computer to judge the quality of the data obtained.

The measurement notes should be given a quick check for completeness, especially to see that the discharge is expressed in metric units, the gage height has been adjusted or weighted if necessary, coefficients have been applied where called for, and the measurement has been rated for quality by the hydrographer who did the field work. The notes are then arranged chronologically and numbered consecutively.

List of Discharge Measurements

For convenience during the computations, part of the information given on the front sheet of the discharge measurement notes is listed on another sheet. The following information is entered in the appropriate column of the list of measurements:

1. Measurement number: Each measurement or observation of no flow is numbered. If more than one discharge measurement is made on the same day they are numbered consecutively by time.
2. Date: Month and day is entered; the year is entered only at the beginning of each calendar year.
3. Made by: Names of the persons who made the measurement. It is customary to list the instrument man first, the note keeper second, and any other persons in the field party last.
4. Width: The width of the stream is the actual width covered by water and does not include bridge piers, pilings, protruding rocks or sand bars.
5. Area: Cross-sectional area (width times depth).
6. Mean velocity: Total discharge divided by total area.
7. Gage height: Correct mean gage height of base gage, recorded to the nearest half centimeter, and adjusted for any datum correction or weighting factor.

8. <u>Discharge</u>: The total discharge. This is the sum of all subsections even if two or more channels existed.

9. <u>Method</u>: Method used in setting the observation depth of the current meter such as .6, .2 and .8, surface or indirect method (slope-area, contracted opening, etc.).

10. <u>Number measuring sections</u>: The total number of subsections where velocity measurements are taken or estimated, plus the two end or bank sections.

11. <u>Gage-height change</u>: Total change during the actual measurement time, including a plus or minus sign to show whether made on a rising or falling stage. If river peaks and starts receding during measurement, show total rise and total fall (+.07, -.05).

12. <u>Time</u>: The elapsed time between the beginning and end of the actual measurement, shown in fractions of an hour (used with gage-height change for weighting gage height. Ignore changes of 0.02 meters or less).

13. <u>Measurement rated</u>: The hydrographer should rate every measurement from the conditions under which the measurement was made and not from its plotted position with respect to the rating curve or other measurements. If the equipment appears to be functioning normally, the cross section boundary is firm, smooth, and uniform, the flow is not affected by eddies, tur-

bulence, waves, or ripples from wind action, then the measurement would be rated as "good". Ratings grade from good to fair to poor, depending upon conditions encountered. The knowledge that some measurements are better than others affect the final records. Excellent ratings are given only to weir and flume measurements.

14. Water temperature: Degrees centigrade (°C) at the time measurement was made.
15. Type of measurement: Whether measurement was made by wading or from cableway, bridge, or boat. A wading measurement is considered to be the most accurate.
16. Remarks: Any information from the field measurement notes that is pertinent to the measurement or rating conditions such as high water marks on or in the stilling well, noticeable change in control, point of zero flow, etc.

In listing, be sure to include the calendar year to avoid confusion later. Also, to simplify reading, leave a blank space between the last measurement made prior to October and the next measurement after September 30 so that measurements made during one water year will stand out and not be confused with those made in other years. Rivers usually are at their lowest stage in September and October, and therefore the "water year" is taken from October 1 to September 30. Figure 6 shows a list of discharge measurements. The columns headed "shift adjustment" and "percent difference" will not be used until the stage-discharge relation is established. It is therefore necessary to return to this form later.

Station No. 0.0.0

Discharge measurements of Diwana Rud near Sadh Sakh, during the year ending Sept. 30, 1967

No.	Date	Made by—	Width	Area	Mean velocity	Gage height	Discharge	Rating Shift adj.	Rating Percent diff.	Method	Number meas. sections	Gage height change	Time	Meas. rated	Temp °C	Type	REMARKS
1	1966 Sept. 11	Hosain - Wali	14.8	5.95	1.18	0.400	7.032			.6	28	0	1/12	G	28	W	PZF = 0.185 ± .002
2	Nov. 17	Rezaq - Qudus	35.5	28.4	1.34	0.835	38.2			.6 2-.8	32	±.003	1 7/12	G	15	C	
3	1967 Jan. 21	Hedayat - Yunus	59.7	95.5	1.37	1.555	131			.6 2-.8	27	±.002	2 1/12	G	5	C	
4	Mar. 30	Kazim - Amir	84.1	185	1.35	2.200	251			2-.8	29	+.010 -.015	1 9/12	G	4	C	Measured at peak.
5	May 17	Amir - Nabi	42.9	47.2	1.37	1.105	64.5			.6 2-.8	26	0	1 5/12	F	7	C	Bad storm - visibility poor - strong wind U.S.
6	June 10	Rezaq - Yunus	20.5	11.1	1.28	0.540	14.2			.6 2-.8	32	0	1 1/12	G	22	W	
7	Sept. 21	Nabi - Kazim	11.9	4.18	1.10	0.390	4.31			.6	24	0	10/12	G	26	W	Moss on control
8	Oct. 14	Qudus - Amir	7.95	1.91	.806	0.240	1.54			.5, .6	27	0	11/12	F	27	W	PZF = 0.190 ± .002

Figure 6.--Preliminary list of discharge measurements.

Copied by Hussain Computed by Checked by

RATING CURVES

The rating curve (figure 7) is a graphic representation of the "stage-discharge relation" for a particular cross section or reach of a stream, or for an artificial control such as a weir. It is used to compute a "rating table" which gives in tabular form the discharges for all stages or gage heights defined by the rating curve. It can be drawn on rectangular coordinate or logarithmic coordinate paper; standard forms are available. The logarithmic forms are the most commonly used because they produce the best graphic form of a standard curve and readily adapt to the use of ship curves; also for a station that has a fairly decent control, the curve tends to be a straight line unless certain aspects of the channel section are out of the ordinary.

Other advantages that logarithmic forms have are: 1) A percentage distance away from the curve is always the same regardless of where it is measured from the curve. Thus, a measurement that is 10 percent off the curve at high water will be the same distance away as a measurement 10 percent off at low water; 2) regardless of the units used (metric or english) the shape and size of the curve will be the same; 3) a curve can be made to approach a straight line by adding or subtracting a constant to the gage-height scale. Halving, doubling, or adding a percentage to the gage-height scale has no affect. The curve will merely shift position but retain the same shape. See figure 8 for examples of gage-height scales.

In plotting discharge measurements, the gage height is the ordinate and the discharge is the abscissa. On rectangular coordinates, scales should be chosen so that gage heights and discharges can be easily read, and arranged so that both the high and low curves are on one sheet. Curves on logarithmic coordinates should be arranged so that the curve falls in the center of the form.

File 0.0.0

Diwana Rud near Sadh Sakh

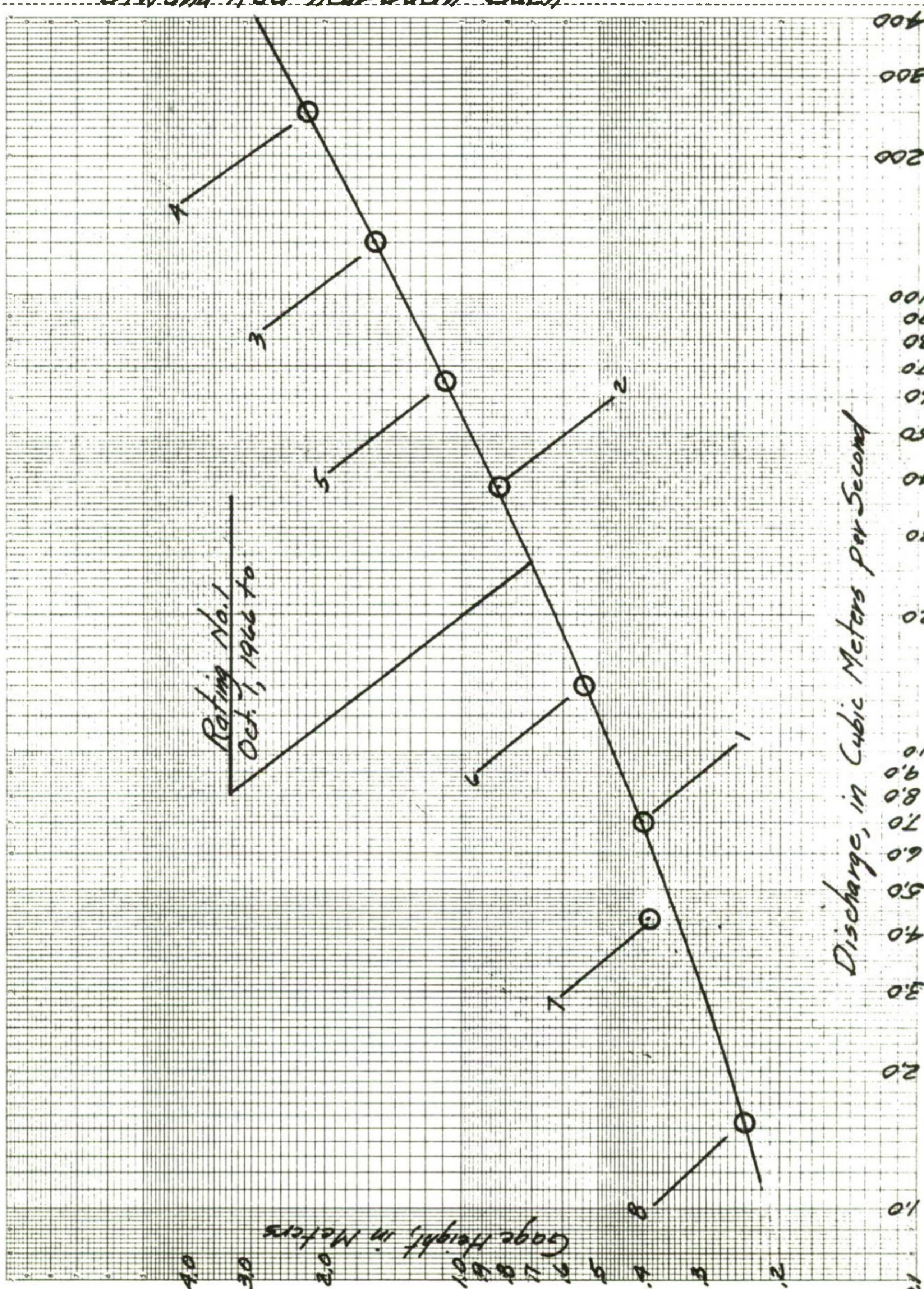


Figure 7.--Logarithmic rating curve.

9-213G

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File ______________

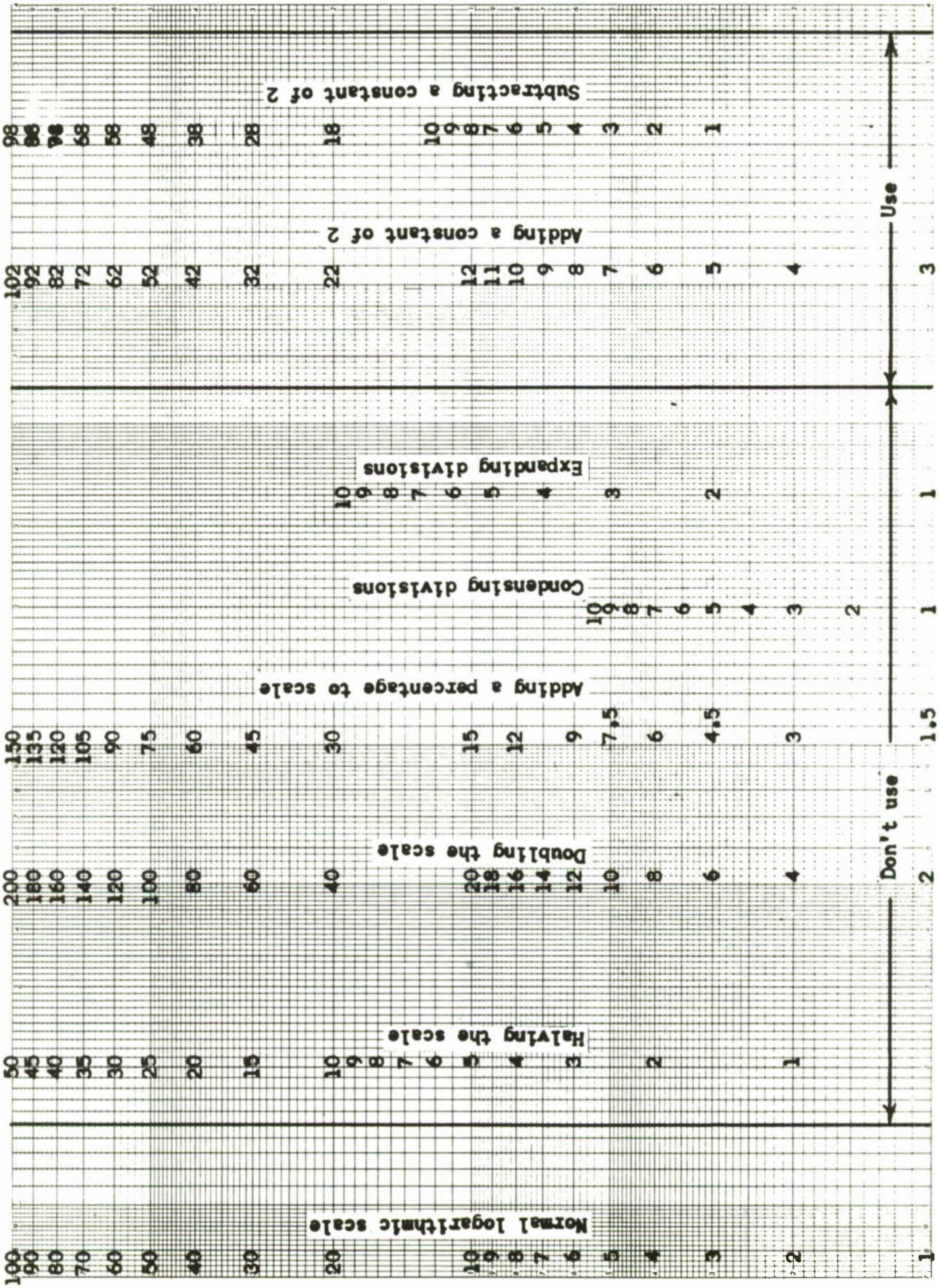


Figure 8.--Logarithmic scales.

Sheet No.____of____sheets. Prepared by________ Date______ Checked by________ Date______

GPO 917-894

GPO : 1958 OF—476256

Plotting Measurements

Place numbers indicating gage height and discharge scales inside or outside the border of the rating curve sheet but be consistent for the particular curve to avoid confusion. Plot the measurements in pencil from the checked "List of Measurements" indicating the point by a small circle with a line extending about two centimeters from it to the measurement number at the end of the line. The plotter then enters the necessary notes on the right margin of the sheet indicating the year, the numbers of the measurements plotted, the maximum and minimum gage-height the curve is used for in that particular water-year, and his initials.

Another man then checks the plotted positions of the measurements and makes a small inked circle with its center at the exact point for gage height and discharge (preferably with a drop-center or swivel pen). He then inks in the lines and figures. For neatness, all lines should be at approximately a 45-degree angle to the sheet. The data on the right margin of the sheet is then checked and inked and the checker enters his initials.

The rating curve is drawn by using either a straight-edge or curves known as "ship" curves. Ship curves are designed from a parabolic formula and quite often a rating curve on rectangular coordinates very closely follows a particular ship curve due to the fact that the discharge of a stream varies, more or less, as some power of the depth of the water. In drawing the curve, consideration should be given to the accuracy of the discharge measurements as indicated by the hydrographer's "rating" of measurements, the "method" (a wading measurement is usually considered better than other methods at or near the same stage), and other items which only experience will bring. A smooth curve usually results. On some streams bank conditions or obstructions in the channel may cause the rating curve to become a compound curve or even a reverse curve. The intent is to draw a curve which will most nearly indicate the stage-discharge relation. Curves that have only a few points are generally not too accurate because the stage-discharge relation has not been well enough defined. A smooth curve is usually the best curve that can be obtained, and if all measurements on which the curve is based are within 5 percent of the curve, no adjustments are made for shifting control conditions.

In drawing a rating curve the point of zero flow should be known in order to shape the lower end of the curve. The point of zero flow is the gage height at which water ceases to flow over the control. This gage height is as important as a discharge measurement and should be obtained whenever the discharge is sufficiently low to provide an accurate determination. It should also be shown in the remarks column in the list of discharge measurements.

The upper end of a rating curve is usually drawn to pass through the highest discharge measurement. Extensions to rating curves above the highest measurement are usually best made by use of logarithmic coordinates. A logarithmic rating curve will approach a straight line when the point of zero flow, approximately, is subtracted from the gage height. An extension greater than 100 percent of the discharge should be avoided.

Although all discharge measurements have been checked and considered correct before plotting, measurements which plot more than 5 percent from the curve should again be inspected for possible errors. Look especially for errors in addition, the use of the wrong current-meter rating table, and the possible need for weighting or adjusting the gage height. If no errors are found, check for notes about channel or control conditions that may account for the divergence. Also check the recorder chart or observer's notes to verify the gage height and to see if any cause can be traced through the chart. Talk to the hydrographer that made the measurement. Quite often they have observed some seemingly minor thing that can account for the discrepancy.

The rating curve is then ready for preparation of the "rating table". The curve is not inked yet because small changes may be necessary after the rating table is made. Figure 7 shows the rating curve developed from the discharge measurements listed on figure 6.

RATING TABLES

The rating table is a tabular form of the rating curve. It is not in itself a computation but merely a useful tool for obtaining the discharge for a given gage height. Figure 9 shows the first step in computing a rating table and the discharges are shown as they were picked off of the rating curve without smoothing. Near the lower end of the curve where the curvature is greatest and the logarithmic scale is at its greatest expansion, the discharge for each 0.01 meter is taken directly from the curve. As the curve approaches a straight line the discharge is picked off only for the 0.05 meter intervals, and then finally only for the 0.10 meter intervals.

The small figures in the upper left corner of each box are the differences between adjacent discharges. These do not always progress upward at an even rate when first picked off the curve. It is necessary to make changes in the discharges so that these differences increase smoothly or are the same as the preceding difference. Figure 10 shows the discharges slightly changed to make the differences progress upward smoothly and the 0.40 to 0.60 meter discharges filled in. Figure 11 shows the completed rating table. In the difference column, the term "curvilinear" means that the change in the slope of the curve is so rapid that the differences change during increments of less than 0.10 meter. For this particular curve, the curve straightens out enough at gage height

0.80 meters so that differences above that point can remain the same for gage height increments of 0.10 meter or larger.

The small figures to the right of the main figures in the difference column are the "second differences" and are useful in smoothing the curve. The second differences must also progress smoothly between adjacent figures but, unlike the first differences, they can progress upward or downward or remain constant. When the second differences change to a downward progression, this indicates a reversal in the rating curve and this may actually be the case where high flows pass through a constriction such as a bridge opening. However, when this occurs in the second differences a close check should be made to verify that this condition actually exists.

At the bottom of the sheet there is always a statement about the measurements used to define the curve, and if an extension of the curve above the highest measurement is made, a statement about the method used for the extension is included. Quite often two or more curves for the same station are identical in shape, slope, and position throughout certain parts, especially at the high end, and it is customary to add a statement at the bottom of the rating table defining the range in which the curves are the same.

The table heading always shows the complete station name and system number, the rating number, and the period or periods of use. A rating always remains in effect until superceded by another rating. Even though the stage-discharge relation may be indefinite at times

Rating table for Sta. No.

Diwana Rud near Sadh Sakh

from to ; from to

from to ; from to

Gage height	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	Difference
0.0											
.1											
.2	0.800	^{15}0.950	^{20}1.15	^{20}1.35	^{20}1.55	^{25}1.80	^{20}2.00	^{30}2.30	^{25}2.55	^{30}2.85	
.3	^{25}3.10	^{30}3.40	^{40}3.80	^{30}4.10	^{35}4.45	^{35}4.80	^{40}5.20	^{40}5.60	^{40}6.00	^{40}6.40	
.4	^{40}6.80					9.00					
.5	^{50}11.8					14.5					
.6	^{60}17.8					21.5					
.7	^{72}25.0										
.8	^{85}33.5										
.9	^{100}43.5										
1.0	^{105}54.0										
.1	^{110}65.0										
.2	^{130}78.0										
.3	^{130}91.0										
.4	^{16}107										
.5	^{14}121										
.6	^{17}138										
.7	^{15}153										
.8	^{19}172										
.9	^{18}190										
2.0	^{20}210										
.1	^{20}230										
.2	^{20}250										
.3	^{20}270										
.4	^{25}295										
.5	^{20}315										
.6	^{25}340										
.7	^{25}365										
.8	^{25}390										
.9											

Computed by / /19 ; Checked by / /19 Remarks

Figure 9.--Preliminary rating table.

Rating table for Sta. No. ....

Diwana Rud near Sadh Sakh Dated ...., 19 ....

from .... to ....; from .... to ....

from .... to ....; from .... to ....

Gage height	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	Difference
0.0											
.1											
.2	0.800	[15] 0.950	[15] 1.15	[20] 1.35	[20] 1.55	[20] 1.75	[25] 2.00	[25] 2.25	[25] 2.50	[30] 2.80	
.3	[30] 3.10	[30] 3.40	[30] 3.70	[35] 4.05	[35] 4.40	[40] 4.80	[40] 5.20	[40] 5.60	[40] 6.00	[40] 6.40	
.4	[40] 6.80	[40] 7.20	[40] 7.60	[40] 8.00	[50] 8.50	[50] 9.00	[50] 9.50	[50] 10.0	[60] 10.6	[60] 11.2	
.5	[60] 11.8	[60] 12.4	[60] 13.0	[60] 13.6	[60] 14.2	[60] 14.8	[60] 15.4	[60] 16.0	[60] 16.6	[60] 17.2	
.6	[60] 17.8	[70] 18.5	[70] 19.2	[70] 19.9	[70] 20.6	[70] 21.3	[70] 22.0	[70] 22.7	[70] 23.4	[80] 24.2	
.7	[80] 25.0	[80] 25.8	[80] 26.6	[80] 27.4	[80] 28.2	[80] 29.0	[90] 29.9	[90] 30.8	[90] 31.7	[90] 32.6	
.8	[9.0] 33.5										
.9	[10.0] 43.5										
1.0	[11.0] 54.5										
.1	[11.5] 66.0										
.2	[12.0] 78.0										
.3	[13.0] 91.0										
.4	[14.0] 105										
.5	[15.0] 120										
.6	[16.0] 136										
.7	[17.0] 153										
.8	[18.0] 171										
.9	[19.0] 190										
2.0	[20] 210										
.1	[20] 230										
.2	[21] 251										
.3	[21] 272										
.4	[22] 294										
.5	[23] 317										
.6	[24] 341										
.7	[24] 365										
.8	[25] 390										
.9											

Computed by .... /...../19.....; Checked by .... /...../19..... Remarks ....

Figure 10.--Intermediate rating table.

Rating table for Sta. No. 0.0.0

Diwana Rud near Sadh Sakh No. 1

from Oct. 1, 1966 to ; from to

from to ; from to

Gage height	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	Difference
0.0											
.1											
.2				1.35	1.55	1.75	2.00	2.25	2.50	2.80	
.3	3.10	3.40	3.70	4.05	4.40	4.80	5.20	5.60	6.00	6.40	
.4	6.80	7.20	7.60	8.00	8.50	9.00	9.50	10.0	10.6	11.2	
.5	11.8	12.4	13.0	13.6	14.2	14.8	15.4	16.0	16.6	17.2	Curvilinear
.6	17.8	18.5	19.2	19.9	20.6	21.3	22.0	22.7	23.4	24.2	
.7	25.0	25.8	26.6	27.4	28.2	29.0	29.9	30.8	31.7	32.6	
.8	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5	42.5	10.0 ,
.9	43.5	44.6	45.7	46.8	47.9	49.0	50.1	51.2	52.3	53.4	11.0 0.6
1.0	54.5	55.6	56.8	58.0	59.1	60.2	61.4	62.6	63.7	64.8	11.6 0.6
.1	66.0	67.2	68.4	69.6	70.8	72.0	73.2	74.4	75.6	76.8	12.0 ,
.2	78.0	79.3	80.6	81.9	83.2	84.5	85.8	87.1	88.4	89.7	13.0 ,
.3	91.0	92.4	93.8	95.2	96.6	98.0	99.4	101	102	104	14.0 ,
.4	105	106	108	110	111	112	114	116	117	118	15.0 ,
.5	120	122	123	125	126	128	130	131	133	134	16.0 ,
.6	136	138	139	141	143	144	146	148	150	151	17.0 ,
.7	153	155	157	158	160	162	164	166	167	169	18.0 ,
.8	171	173	175	177	179	180	182	184	186	188	19.0 ,
.9	190	192	194	196	198	200	202	204	206	208	20.0 0
2.0	210	212	214	216	218	220	222	224	226	228	20.0 ,
.1	230	232	234	236	238	240	243	245	247	249	21.0 0
.2	251	253	255	257	259	262	264	266	268	270	21.0 ,
.3	272	274	276	279	281	283	285	287	290	292	22.0 ,
.4	294	296	299	301	303	306	308	310	312	315	23.0 ,
.5	317	319	322	324	327	329	331	334	336	339	24.0 0
.6	341	343	346	348	351	353	355	358	360	363	24.0 ,
.7	365	368	370	372	375	378	380	382	385	388	25.0
.8	390										
.9											

Computed by Husain 12/9/1967; Checked by Anwar 12/12/1967 Remarks Based on measurements No. 1 to 8 made between Sept. 11, 1966 and Oct. 14, 1967. Extended above 2.20 meters by logarithmic plotting.

Figure 11.--Completed rating table.

because of mechanical troubles (recorder malfunctioning, well silted, etc.), or channel conditions (debris on control, shifting sand or gravel, backwater from diversions, etc.) a rating is always effective during these periods and proper notations are made on the forms to account for the periods of indefinite stage-discharge relation.

In the above discussion of rating curves and rating tables the instructions are for times when new curves and tables are needed. In actual practice it will be found that a rating curve and table for a certain station might be used for many years before conditions change sufficiently to require new curves and tables. In this case, those measurements made after the curve was drawn are added to the old curve until such time as it appears a new rating will be needed.

DAILY GAGE HEIGHTS AND DISCHARGE LISTING

The daily gage heights and discharges are listed on a form that will be reproduced in the final publication of the records. The form is designed to span a water year from October 1 to September 30, and is not only used to list daily mean gage heights and daily mean discharges, but also for computation of monthly and annual totals, means, maximum and minimum discharges, as well as the footnotes and other data which help to interpret the record. The form contains all the information usually necessary or desirable for one water year for a particular streamflow or reservoir gaging station. Figure 12 shows a completed form.

Place name of station and year at top of sheet. The name should be identical to that given in the station description to avoid confusion with other stations on the same stream. For example, if the correct name is "Diwana Rud near Sadh Sakh" do not use "Diwana Rud at Sadh Sakh". From the list of discharge measurements indicate the number of each measurement made during the year on its proper date in a small, neat box in the upper left corner of the discharge column.

The next step in the computations is the listing of gage heights on this form or the computation of "shifts" and "percentages" on the list of measurements form. The latter will be discussed first as oftentimes two men work together on a set of records and the steps are done simultaneously.

Shifts

On the list of measurements are columns headed "Rating", with subheadings of "Shift Adjustment", and "Percent Difference" which were not previously discussed in section 3.200. The shift adjustment is used to adjust the rating curve to a discharge measurement. In so doing, it is assumed that the discharge measurement is correct and that at the time of measurement the stage-discharge relation as given by the rating curve and the rating table was not effective because of a change in the control called a "shift", caused by silting, scouring, backwater from weed growth, effect of small dams and dikes, or other reasons. On streams with sand or gravel bottoms, shifts usually occur during or after the peak of flash floods or rises, while on streams with rock or very coarse gravel controls shifts seldom occur. To illustrate how such shifts are caused, inspection of cross sections of the Helmand River near Chahar Burjak show that the river bottom goes down as the river stage comes up, and as the flood or high water passes there is a dropping of gravels, sand, and silt to again bring the river bed to its former condition. However, the condition will not be exactly the same as before so that a small "shift" may be shown by the next measurement.

To compute the percent difference enter the applicable rating table with the gage height of the measurement and obtain the rating table discharge for that stage. Compute the percent difference by subtracting the rating table discharge from the measured discharge and divide the difference by the rating table discharge, to the nearest tenth percent. If the measured discharge is larger than the rating table discharge the difference is plus and the percentage will be plus; if the measured discharge is smaller, the percentage will be minus. For example, if at gage height 2.380 meters the measured discharge was 286 cumecs and the rating table discharge 290 cumecs, then 286-290 = -4 divided by 290 = -0.0138 or -1.4 percent. The percent difference with the appropriate sign is then entered in the column to the nearest tenth percent.

If the difference between the rating table discharge and the measured discharge is less that 5 percent place a dash in the shift column for that measurement. This means that the rating table is to be used direct at that time and stage. When a rating curve is a mean curve through the plotted points and the discharge measurements plot within 5 percent of that rating with some plus and some minus, it is usually acceptable to use the rating direct without adjustments for shifting control. If, however, a series of measurements plot consistently to one side this indicates that a shift has occurred and such measurements would be shifted to by a uniform, or average, shift or to each measurement individually. Fairly large shifts may occur on a rise or recession and if the shifts are defined by measurements it is necessary to adjust to such condition. Backwater from moss, weeds, etc., will cause a progressive shift while diversions

Diwana Rud near Sadh Sakh - 1967

Daily Gage Height, in Meters and Discharge, in Cumecs of Diwana Rud near Sadh Sakh for the Year Ending September 30, 1967

Rating No. 1 — Periods of use: Oct. 1 to Sept. 30 — Use half-tenths for all stages

File Number 0.0.0

Drainage area 17,350 Square km. Type of gage Stevens A35 Observer reads staff gage twice daily

Max Disch 388 cumecs at 1800 on Mar. 7 G.H. 2.790 M
Min Disch 3.88 cumecs on Sept. 30 G.H. 3.70-.025 M

Peak discharge (Base 250 cumecs) -- Mar. 7 (1800) 388 cumecs (2.790M); Mar. 16 (0630) 312 cumecs (2.480M); Mar. 30 (1400) 253 cumecs (2.210M); Apr. 11 (2300) 302 cumecs (2.435M); Apr. 26 (0900) 279 cumecs (2.335M)

Day	October Gage height	October Discharge (1) Sept. 11)	November Gage height	November Discharge	December Gage height	December Discharge	January Gage height	January Discharge
1	0.835	37.0	0.825	36.0	0.855	39.0	1.050	60.2
2	.835	37.0	a	36	.855	39.0	1.030	58.0
3	.835	37.0	Clock stopped - Range in stage 0.780 to 0.825	35	.865	40.0	1.030	58.0
4	.835	37.0		35	.855	39.0	1.030	58.0
5	.835	37.0		35	.865	40.0	1.015	56.2
6	.835	37.0		34	.855	39.0	1.015	56.2
7	.835	37.0		34	.860	39.5	1.030	58.0
8	.835	37.0		32	.875	41.0	1.050	60.2
9	.835	37.0		32	.880	41.5	1.050	60.2
10	.835	37.0		33	.885	42.0	1.065	62.0
11	.835	37.0		33	.885	42.0	1.065	62.0
12	.835	37.0		33	.890	42.5	1.125	69.0
13	.835	37.0		32	.900	43.5	1.150	72.0
14	.845	38.0		32	.905	44.0	1.150	72.0
15	.845	38.0		34	.905	44.0	1.135	70.2
16	.845	38.0	a	34	.910	44.6	1.110	67.2
17	.845	38.0	.825	3) 36.0	.920	45.7	1.100	66.0
18	.845	38.0	.825	36.0	.930	46.8	1.090	64.8
19	.845	38.0	.825	36.0	.940	47.9	1.085	64.2
20	.845	38.0	.825	36.0	.960	50.1	S	150
21	.845	38.0	.835	37.0	1.040 b	50	1.575	3) 132
22	.845	38.0	.845	38.0	1.155	50	1.510	122
23	.845	38.0	.915	45.2	1.225	50	1.430	110
24	.845	38.0	.980	52.3	1.290	50	1.365	100
25	.845	38.0	.920	45.7	1.225	50	1.330	95.2
26	.845	38.0	.900	43.5	1.185	60	1.300	91.0
27	.825	36.0	.875	41.0	1.150	60	1.285	89.0
28	.825	36.0	.865	40.0	1.115	60	1.280	88.4
29	.825	36.0	.855	39.0	1.100	60	1.275	87.8
30	.825	36.0	.855	39.0	1.085	60	1.270	87.1
31	.825	36.0			1065 b	60	1.265	86.4
Total		1,155.0		1,104.7		1,461.1		2,433.3
Mean		37.26		36.82		47.13		78.49
Million M³		99.79		95.45		126.2		210.2
Maximum		38.0		52.3		60		150
Minimum		36.0		32.0		39.0		56.2

Day	February Gage height	February Discharge	March Gage height	March Discharge	April Gage height	April Discharge	May Gage height	May Discharge	June Gage height	June Discharge
1	1.265	86.4	1.235	82.6	1.910	192	1.895	189	0.690	24.2
2	1.265	86.4	1.235	82.6	1.865	183	1.850	180	.675	23.0
3	1.245	83.8	1.245	83.8	1.800	171	1.795	170	.645	20.9
4	1.245	83.8	1.270	87.1	1.770	166	1.745	161	.630	19.9
5	1.245	83.8	1.285	89.0	1.740	160	1.690	151	.620	19.2
6	1.265	86.4	S	90.4	1.690	151	1.635	142	.605	18.2
7	1.265	86.4	S	346	1.670	148	1.560	130	.590	17.2
8	1.265	86.4	S	300	1.635	142	1.500	120	.570	16.0
9	1.280	88.4	2.345	282	1.625	140	1.430	110	.555	15.1
10	1.280	88.4	2.185	248	1.750	162	1.355	98.7	.540	5) 14.2
11	1.280	88.4	2.095	229	S	301	1.330	95.2	.520	13.0
12	1.330	95.2	2.005	211	2.465	309	1.300	91.0	.520	13.0
13	1.440	111	1.850	180	2.410	296	1.270	87.1	.505	12.1
14	1.500	120	1.815	174	2.380	290	1.230	81.9	.490	11.2
15	1.425	109	S	253	2.330	279	1.175	75.0	.470	10.0
16	1.370	101	2.280	268	2.295	271	1.135	70.2	.460	9.50
17	1.350	98.0	2.240	259	2.250	262	1.090	5) 64.8	.450	9.00
18	1.305	91.7	2.195	250	2.200	251	1.055	60.8	.445	8.75
19	1.285	89.0	2.095	229	2.150	240	1.040	59.1	.435	8.25
20	1.260	85.8	2.040	218	2.100	230	.995	54.0	.430	8.00
21	1.240	83.2	2.000	210	2.060	222	.960	50.1	.450	9.00
22	1.215	80.0	1.950	200	2.000	210	.935	47.4	.465	9.75
23	1.215	80.0	1.910	192	1.950	200	.905	44.0	.455	9.25
24	1.210	79.3	1.855	181	1.890	188	.845	38.0	.440g	8.50
25	1.210	79.3	1.840	179	1.855	181	.825	36.0	.430	8.00
26	1.230	81.9	1.795	170	2.195	250	.805	34.0	.410	7.20
27	1.230	81.9	1.750	162	2.135	237	.770	30.8	.405	7.00
28	1.235	82.6	1.740	160	2.045	219	.750	29.0	.400	6.80
29			1.875	5) 185	2.000	210	.735	27.8	.400	6.80
30			2.145	239	1.950	200	.720	26.6	.395g	6.60
31			1.965	203			.700	25.0		
Total		2,497.5		6,043.5		6,461		2,579.5		369.60
Mean		89.20		195.0		215.4		83.21		12.32
Million M³		215.8		522.2		558.2		222.9		31.93
Maximum		120		346		309		189		24.2
Minimum		79.3		82.6		140		25.0		6.60

Day	July Gage height	July Discharge	August Gage height	August Discharge	September Gage height	September Discharge
1	0.390g	6.40	.360g:.045	4.60	.380g:.040	4.40
2	.385	6.20	.360	4.60	.380	4.40
3	.380	6.00	.360	4.60	.380	4.40
4	.375	5.80	.360	4.60	.380	4.40
5	.370	5.60	.360	4.60	.380:.040	4.40
6	.365	5.40	.365:.045	4.80	.385:.040	4.40
7	.360	5.20	.370:.020	4.80	.385g:.045	4.40
8	.360	5.20	.370	4.80	a	4.4
9	.360	5.20	.370	4.80	No gage height record	4.4
10	.360	5.20	.370	4.80		4.4
11	.360	5.20	.370	4.80		4.3
12	.360	5.20	.370:.020	4.80		4.3
13	.360 o	5.20	.375:.025	4.80		4.3
14	.360:.005	5.00	.375	4.80		4.3
15	.360	5.00	.375	4.80		4.3
16	.360	5.00	.375	4.80		4.2
17	.360	5.00	.375	4.80		4.2
18	.360	5.00	.375:.025	4.80		4.2
19	.360	5.00	.385:.030	5.00		4.2
20	.360	5.00	.385	5.00	a	4.2
21	.355	4.80	.385	5.00	.390:.065	7) 4.22
22	.355	4.80	.385	5.00	.390:.065	4.22
23	.355:.005	4.80	.385	5.00	.385:.050	4.22
24	.355:.010	4.60	.385:.030	5.00	.385	4.22
25	.355	4.60	.380:.035	4.60	.385	4.22
26	.355	4.60	.380	4.60	.385	4.22
27	.355	4.60	.380	4.60	.385:.050	4.22
28	.355	4.60	.380	4.60	.375:.045	4.05
29	.355	4.60	.380	4.60	.375	4.05
30	.355	4.60	.380:.035	4.60	.375:.045	4.05
31	.355g:.010	4.60	.380g:.040	4.40	8) Oct. 14	
Total		158.00		147.40		128.19
Mean		5.097		4.755		4.273
Million M³		13.65		12.74		11.08
Maximum		6.40		5.00		4.40
Minimum		4.60		4.40		4.05

Period: Water Year 1967

Calendar Year	
Total	24,538.79
Mean	67.23
Million M³	2,120
Maximum	346
Minimum	4.05

Remarks:
S - subdivided day.
a - No gage height record.
b - Ice-affected. No stage-discharge relation.
g - Computed from twice-daily staff gage readings.

Note - Records good except those for periods of no gage-height or indefinite stage-discharge relation which are fair.

Computations: Computed Hekmat — Checked Omar — Date 12-14-67
Discharge: Applied Raz — Checked Amir — Date 12-14-67
Gage height: Computed Amir — Checked Raz — Date 12-13-67

Figure 12.--Daily gage height and discharge listing.

for irrigation jueys will cause a very erratic shift as they deteriorate and are repaired. Because the stage-discharge relation represented by the rating table is not valid for these conditions, shifts or adjustments must be used to provide the true discharge defined by the measurements.

To compute a shift, if the percent difference was greater than 5 percent, the rating table is entered with the measured discharge, and the corresponding gage height for the discharge closest to the measured discharge noted. The difference between the measurement gage height and the rating table gage height is the "shift adjustment". Subtract the observed gage height from the rating table gage height and enter this figure in the shift adjustment column with the appropriate sign (+ or -). Usually, the rating table discharge will not agree exactly with the measured discharge so that the "percent difference" must also be computed as explained above, except that the percentage is based on the shifted position of the curve. For example, if the measured discharge was 277 cumecs at 2.380 meters and the rating table discharge for that gage height was 290 cumecs, enter the table with 277 cumecs and you find the nearest discharge is 276 cumecs at 2.320 meters. Then 2.320 - 2.380 = -0.060 meters, which is the shift, and 277 - 276 = +1 divided by 276 = +0.004 = +0.4 percent.

The shift adjustments should be checked before further use in the computations. An excessive shift (which also would be detected by the plotted points on the rating curve) should be studied, and if the measurement shows indication of faulty equipment or was poorly made, the measurement should be disregarded. Figure 13 shows the list of measurements with the "rating" columns completed.

The daily gage heights are listed on the computation form and checked before further use. The man who listed the gage heights and the man who checked the work should place their initials in the box near the right margin. Gage heights should be inked legibly and neatly after being checked.

If no shift adjustments are to be used during the year the daily discharges are applied on the computation form by reading the discharge from the rating table for each daily gage height. As the listed gage heights are the daily mean gage heights, the discharges will also be the daily mean discharges, except during a rapid change in stage when it will be necessary to subdivide the day to obtain the correct dishcarge. (Such subdivision is necessary due to the curvature of the rating curve. A low discharge would result if the daily mean gage height were used.) Days which must be subdivided should have been already subdivided on the recorder chart while computing the mean gage heights. It is necessary, therefore, to apply discharges for those parts of the day to obtain the weighted mean discharge. See section 2.140 for methods of subdividing.

For periods when shift adjustments are used, the shifts (as computed and entered on the list of measurements) are placed in the shift column on the same days where the measurements are indicated. By studying the gage height record and measurement notes the reason for the shift may become apparent and the system of applying shifts

Station No. 0.0.0

Discharge measurements of Diwana Rud near Sadh Sakh, during the year ending Sept. 30, 1967

No.	Date	Made by—	Width	Area	Mean velocity	Gage height	Discharge	Rating No.1 Shift adj.	Rating No.1 Percent diff.	Method	Number meas. sections	Gage height change	Time	Meas. rated	Temp. °C	Type	REMARKS
1	1966 Sept. 11	Hosain - Wali	14.8	5.95	1.18	0.400	(6.800) 7.032	-	+3.4	.6	28	0	11/12	G	28	W	PZF=0.185±.002
2	Nov. 17	Rezaq - Qudus	35.5	28.4	1.34	0.835	(37.0) 38.2	-	+3.2	.6 2-8	32	+.003	17/12	G	15	C	
3	1967 Jan. 21	Hedayat - Yunus	59.7	95.5	1.37	1.555	(129) 131	-	+1.6	.6 2-8	27	+.002	21/12	G	5	C	
4	Mar. 30	Kazim - Amir	84.1	185	1.35	2.200	(251) 251	-	0	2-8	29	+.010 -.015	19/12	G	4	C	Measured at peak.
5	May 17	Amir - Nabi	42.9	47.2	1.37	1.105	(66.6) 64.5	-	-3.2	.6 2-8	26	0	15/12	F	7	C	Bad storm - visibility poor - strong wind U.S.
6	June 10	Rezaq - Yunus	20.5	11.1	1.28	0.546	(14.2) 14.2	-	0	.6 2-8	32	0	11/12	G	22	W	
7	Sept. 21	Nabi - Kazim	11.9	4.18	1.10	(0.325) 0.390	(4.22) 4.31	-.055	+2.1	.6	24	0	19/12	G	26	W	Moss on control
8	Oct. 14	Qudus - Amir	7.95	1.91	.806	0.240	(1.55) 1.54	-	-0.6	5.6	27	0	11/12	F	27	W	PZF=0.190±.002

Copied by Hussain Computed by J. Mohd Checked by Qudus

Figure 13.--Completed list of discharge measurements.

between days of measurements decided on. If shifts change with stage, the intervening shifts will be graduated by stage; if shifts change without substantial change in stage, the shifts will be graduated by time. If a rise occurred between measurements and the shift changed, the shift may have happened as a result of the rise. If work is known to have been performed on the control between measurements, an inspection of the recorder chart may furnish clues as to when the work was done. The shifts should be shown in neat small figures to indicate the days of use of the same shift. The plus and minus signs must be closely watched because an error in sign may introduce an appreciable error in discharge. Look back at the plotted points on the rating curve to see if the signs are correct. If the shift varies during a day, such as when the shift was caused by a flash flood, a "V" (indicating a variable shift for the day) is placed in the shift column, and the actual variable shift is given on the recorder chart where the day is computed by subdividing the day. No gage height is used for a subdivided day; the letter "S" (meaning subdivided) is put in that column for the day.

When the shifts have been entered on the form, the shift for the day should be added to or subtracted from the gage height before entering the rating table to obtain the discharge. The shift should not be forgotten when computing subdivided days and, also, a gage height correction may have been in use on that day and must also be used in the subdivided day computation.

The distribution of shifts and application of discharge should be checked by another person and his initials entered in the box on the right margin of the form. However, it is good practice to plot a hydrograph (see section 7.000) to visually locate doubtful discharge before inking the discharges. Also, the monthly discharge should be totaled before inking so that the checking of totals will also serve as a check on the inking of penciled figures (a very common error in inking is transposing figures). The figures should be legible and neat, with decimal points and commas lined up.

Monthly Summaries

After the application of discharge has been checked and inked, the hydrograph studied and compared with records for a station on the same or nearby streams, the monthly and annual summaries are completed.

From the checked monthly total cumecs compute the monthly mean by dividing the total by the number of days in the month and enter it to three significant figures if under 1,000 cumecs (except not to exceed one more significant figure than the daily figures) and to four significant figures if 1,000 cumecs or more. (See section 10.100 for explanation of significant figures.)

The daily maximum and minimum discharges for each month are entered at the bottom of the form from an inspection of the listed discharges and checked against the high and low on the hydrograph form.

Yearly Summaries

The annual water-year summary is computed by summing the total monthly cumecs for the 12 months and entering to the exact figure for the annual total. The annual mean is computed by dividing that total by the number of days in the year. The maximum and minimum daily figures are taken from the monthly figures. The calendar year summary is computed in like manner except that the calendar year instead of the water year is used.

The persons who computed and checked the monthly and annual summaries should enter the date and their initials in the box on the right margin of the sheet. When the computations have been checked they are inked and the figures lined up for easy reading by keeping decimals and commas in line.

Peak Discharges

Peak discharges during the year are listed on the lines under the momentary maximum and minimum figures at the left of the sheet. Peak discharges furnish useful data on the magnitude and frequency of floods. The gage height of the base above which peaks are listed can be found from former records, or if not previously computed, the base is chosen so that peak discharges will exceed it about 3 or 4 times a year over a long period of record. Peak discharges are not listed for stations where the discharge is regulated. List on a separate sheet the date, time, discharge, and gage height for each of the peak stages which exceed the base. Many secondary peaks may occur on a rise due to the timing of flood peaks on tributaries entering the main stream; therefore, eliminate all but the highest which occur within 48 hours of each other unless definitely caused by a separate storm. Ignore the lesser of two peaks if the trough between does not drop more than 25 percent below the lower peak. The peak discharges are listed as follows: Peak discharge (base, 800 cumecs). -- Mar. 2 (0300) 1,040 cumecs (gage height 2.42 meters); Apr. 4 (1030), etc.

Extremes

The highest or momentary maximum discharge for the year and its corresponding gage height are entered on the left margin. It is qualified, as necessary, if it is a maximum daily rather than an instantaneous discharge or if caused by unusual circumstances. The maximum gage height is also entered if different from that for the maximum discharge. The minimum discharge, or minimum daily discharge and its corresponding gage height, is entered and qualified if necessary. If the minimum gage height is different than that for the minimum discharge, it is also listed.

Footnotes

The notes covering special items or symbols used in the computations are added in the space provided at the right side of the form. Certain footnotes are standardized to prevent confusion. These are:

a - No gage-height record

b - Stage-discharge relation affected by ice

d - Doubtful gage-height record

f - Fragmentary gage-height record; discharge computed from partly estimated gage heights

g - Computed from twice daily staff gage readings (This note is used only for stations equipped with water-stage recorders during periods when the recorder was not operating. For stations with staff gages only, the note in the heading of the form indicates the type of gage.)

S - Subdivided day

V - Variable shift

A note indicating the overall accuracy of the record is also included such as "Records good except those for periods of no gage height record which are fair", or some similar notation to the user that certain portions of the record are better than others.

The data on the left margin are then checked by the person who has computed or checked the main records and is familiar with them and, preferably, with field conditions at the station. The computations for that particular year are now complete except for other necessary items, such as the hydrograph, which may be desirable to users of the record. The one computation sheet, however, contains all the pertinent information for that gaging station for that year.

HYDROGRAPH

The hydrograph is a plot of discharge against time. It is plotted with daily mean discharge as the ordinate and days as the abscissa. The standard forms available have either a logarithmic or rectangular scale for the discharge; the time scale is the same on both types. Usually the logarithmic form is used for natural stream channels because this scale condenses the high discharges and expands the low discharges. Figure 14 shows a completed hydrograph.

The purpose of the hydrograph is to give a visual presentation of the daily mean discharges. An experienced hydrographer can easily detect gross errors in computations, and by comparison with hydrographs from nearby stations with similar flow characteristics fill in periods of missing or doubtful discharge.

When the discharge measurements are plotted on the hydrograph, they should be close to or on the discharge line. If they are not, check for reasons why. Usually, the only valid reason for a measurement to plot off the discharge line is because of a large change in stage during the day the measurement was made. If there was no large change in stage, there are probably gross errors in the computations and these must be corrected.

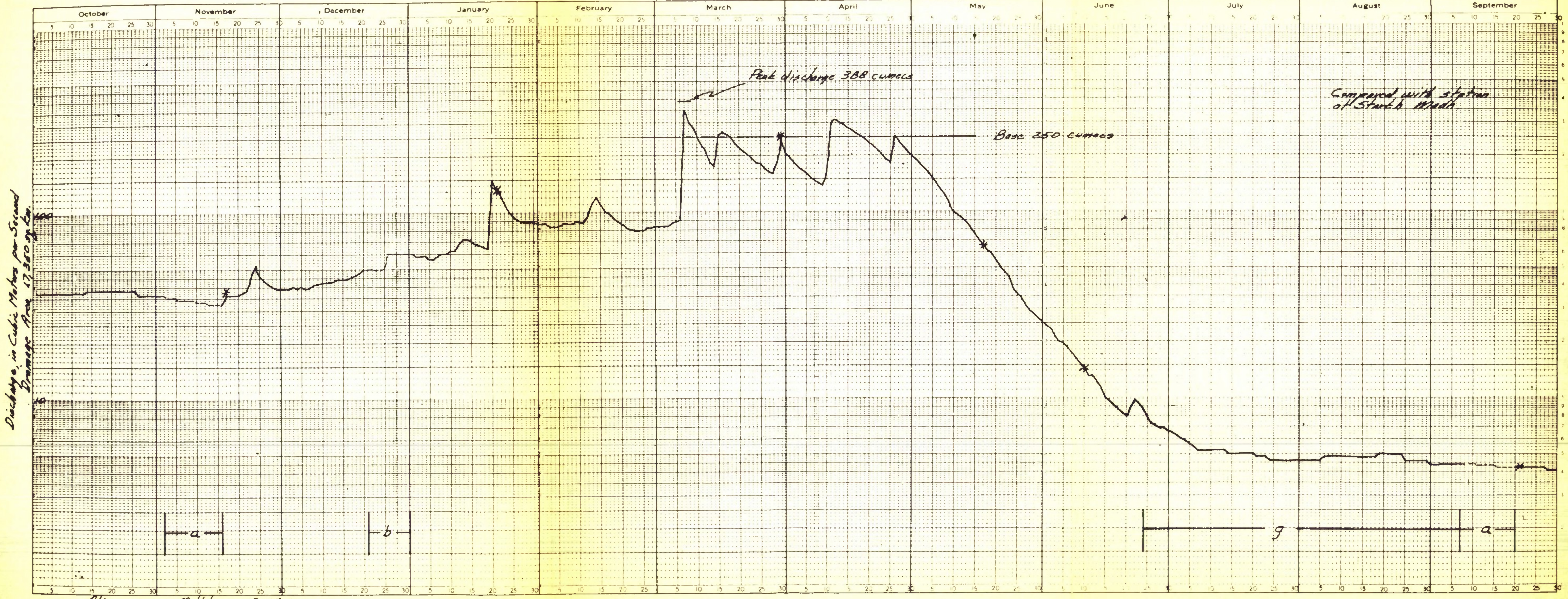
Only one year of record for a single station is plotted on one hydrograph. The footnotes designating a, b, d, f, or g days are also added. Estimated periods are filled with a dashed line.

The momentary maximum is shown on the proper date. The water year designation is placed under the station name.

When estimating periods that are ice-affected, it is helpful to plot the temperature record from a nearby weather station near the top of the sheet. Plot the maximum and minimum temperatures for each day and then shade with red pencil the temperatures above freezing, and with blue pencil the temperatures below freezing. This helps define the period of the greatest ice affect.

HYDROGRAPH FOR Diwana Rud near Sadh Sakh 1967

Sta. No. 0.0.0



Plotted by Ali Checked by Moh'd Date 12-15-67

Figure 14.--Hydrograph.

STATION ANALYSIS

For persons studying the records at a later date, and for review of the records by the engineer-in-charge, the person computing the records for a station should prepare a "station analysis". The analysis includes information in sufficient detail for the reviewer to follow the reasoning and understand the decisions of the computer. The station analysis is a narrative type report and no printed forms are used. Certain information must be included, however, and the analysis generally has the following outline:

Equipment.--Give a short description of station equipment, such as recorder type, staff gage, etc. If any changes, improvements, etc., were made during the year give the date of such change. If no changes were made give a statement to that effect.

Gage-height record.--Give a brief summary of the gage-height record, particularly as to its completeness and accuracy. If parts of the record were from different gages, indicate this. If there were periods of doubtful or no gage-height record give this and the reason; also, if the record is available but not usable give the reason for disregarding such record. If the gage heights have been computed from a reconstructed graph of observer gage readings this should be mentioned. Any information which aids in an understanding of the reliability of the record should be included.

Datum corrections.--Gages should be checked by levels at least once each year to determine if there has been settling of the well or damage from high water. Give dates that gages were checked by levels and the results of the levels. If datum corrections are made show dates the gage was reset or adjusted.

Rating.--Give number of discharge measurements made during the year and if any are disregarded in the rating or in the computations, give the reason. Explain how and why a new rating curve was drawn, or if a previous rating curve was continued in use, explain why. Give some information about the control to show why shifts have or have not occurred. Give any other information which will enable a reviewer to understand your reasons and judgements in the use of a certain rating, the extension of a rating, or other assumptions made to define the stage-discharge relation for the station. Give the rating table dates and period or periods of use. Explain if table was used directly or with adjustments for shifting control. If shifts were used explain how they were distributed or graduated between discharge measurements.

Special methods.--For periods of no gage-height record, tell how discharge was obtained. If discharge was affected by ice or if periods of doubtful gage-height record are used, explain the basis of any estimates, temporary shifts, or other method of arriving at the discharge.

Remarks.--Give your estimate of the overall accuracy of the record and qualify such portion of the record which does not meet the accuracy of the better part of the record. If the records are believed with 5 percent of the true discharge they may be called good, if within 10 percent they may be called fair. An error of 0.010 meter in gage height may often be greater than 5 percent in discharge and from your experience in making and plotting measurements you will recall that many measurements are not within 5 percent or even 10 percent. Many measurements must be disregarded due to obvious regulation. State in this paragraph whether or not the record was compared to a nearby station or stations for consistence and maximum and minimum flow periods.

Recommendations.--Make any recommendations as to any changes that could benefit the station records; if none needed, say so.

Thermograph record.--Some gaging stations will be equipped with a thermograph attachment to the A35 recorder that will give a continual record of the water temperature on the same chart as the gage-height trace line appears on. The daily mean water temperatures must be computed from the trace line, and from these daily figures the monthly and annual mean, and maximum and minimum temperatures are computed. Give a summary of the thermograph record as to its completeness and reliability, reasons for unreliable or missing record, and explain any abnormal highs or lows if the reason can be found. If, during periods of unreliable or missing record, the temperatures were computed from observer's notes explain how the maximums and minimums were obtained. Include any remarks pertinent to the thermograph record and the computations.

The analysis should not be unnecessarily long but should furnish in brief style all the important factors that were considered in the computations. The reviewer can then check your work and either agree with you or have a basis to question your judgement if, in his greater experience, he may interpret the base data differently.

A sample station analysis, based on the data used for illustration in the preceding sections, is given on the following pages.

SAMPLE

0.0.0. Diwana Rud near Sadh Sakh

STATION ANALYSIS

Equipment.--Stevens A35 recorder in 24-inch CMP stilling well on left bank 50 meters above bridge. Type A wire-weight gage on DS side of bridge between left bank pier and middle pier. Staff gage in 3 sections, 2 on 4-inch metal pipes 3 meters US from well, top section on well. No changes during the year except for moving wire weight gage from right of middle pier to present location on June 10. High water measurements made from bridge.

Gage-height record.--Complete and accurate except for the periods Nov. 2-16 when the clock was stopped; Dec. 21-31 which was ice affected; June 24-Sept. 20 when the well was silted. Period June 24 to Sept. 7 based on twice-daily staff gage readings.

Datum corrections.--None. Levels run June 10 to reset wire-weight gage. All other gages check within ± 0.002 meter.

Rating.--The high and medium water controls are bedrock outcroppings just upstream from bridge. At extreme high stages some backwater effect from bridge may be observed. Low water control is sand and gravel riffle 10 meters below gage and is subject to shifting at all stages.

Six discharge measurements, No's. 2-7, were made during the year. Measurement No. 1 was made September 11 before the record was started and No. 8 was made October 14 after the end of the water year.

All measurements except No. 7 were used to compute rating No. 1. This is a new station and no previous rating exists. Measurement No. 7 indicates a shift due to moss on the control and this shift was prorated on a time basis from July 14 to September 7 and September 21-30.

Special methods.--Discharge for period Nov. 2-16 was estimated from recorded range in stage and observer's notes. Discharge for period of ice affect Dec. 21-31 estimated by interpolation. Discharge for period Sept. 8-20 estimated on basis of hydrographic comparison with records for station at Starkh Madh, 35 kilometers upstream.

Remarks.--Records good except those for periods of no gage-height record or indefinite stage-discharge relation which are fair. Hydrographic comparison made with station at Starkh Madh, 35 kilometers upstream.

Recommendations.-- Observer should be instructed to obtain a substitute when he is away on vacation. No records were kept when he was gone Sept. 8-20. Also, he should be instructed to keep control free of ice. Ice affect is not great at this station but it could be eliminated in most years if observer cleans ice off control before it has a chance to build up.

REVIEW OF RECORDS

The review of the completed records by an experienced hydrologist is an important part of the computation procedure and should not be neglected. This is especially true in the Water and Soil Survey Department where the majority of technicians are relatively inexperienced. In the computation process, much depends on the experience, intelligence, and reasoning ability of the individual, and mistakes in logic can easily creep in. Normally, the most experienced hydrologist is designated to do the reviewing but even an experienced man may forget important items if he doesn't have a checklist to follow. The following paragraphs are designed to lead the reviewer through a systematic and logical procedure for the review of streamflow records.

Rating Curve and Table

Rating Curve:

1. Spot check the plotting of discharge measurements. Make sure all measurements used to define the stage-discharge relation are plotted.
2. Check the gage height and discharge scales for accuracy and readability.
3. Check the placement of the curve for accuracy.
4. See that the curve extends only through the range of gage heights for that year.
5. If curve has been extended above the highest measurement, check the reliability of the extension by an alternate method (velocity-area studies, $A\sqrt{d}$, d-Q', etc.).
6. Check rating number and period of use against list of discharge measurements, rating table, station analysis, and the table of daily gage heights and discharges.
7. Check box on right margin for correct entries for current year.

Rating Table:

1. Check table against range of gage heights
2. Spot check gage heights and discharges against rating curves.
3. Check periods of use against rating curve.

4. Check statement at bottom of form for measurements used to define rating, extensions of rating, and range in which table is the same as any previous rating.
5. Check differences for continuity and smoothness.

List of Discharge Measurements

1. Spot check percent difference and shift adjustment entries.
2. Check point of zero flow notations against rating curve and momentary minimum entries on daily gage height and discharge form.
3. Check against daily gage height and discharge form for observations of no flow.

Station Analysis

Since this is a narrative type of report and most of it is engineering interpretation, the reviewer should check for overall reasoning and logic. Unless the reviewer can prove that the computer's assumptions, reasoning, or logic are wrong, he should not attempt to make changes based only on personal opinion nor should he force lengthy recomputations if the final figures will not be greatly affected. The reviewer should concentrate his efforts toward substantiating and verifying the computer's approach to the solution.

Some items should be checked against the computations such as the data in the gage-height record paragraph, the measurement numbers that the rating was based on, and the data in the special methods paragraph.

Hydrograph

1. Check discharge measurements for proximity to flow line.
2. Check periods of estimated or qualified record.
3. Check for unreasonable rises or recessions.
4. Compare with hydrograph at nearby station.
5. Check maximum daily discharge and peak discharge.
6. Check periods of ice-affect against nearby temperature record.
7. Check continuity at points of scale change.
8. Spot check flow line at 4 or 5 places for accuracy of plotting.
9. Check for abrupt rise or fall of flow line at points of rating change.

Daily Gage Height and Discharge Form

1. Using the rating tables listed at top of form, spot check discharges against daily gage heights at 8 or 10 places. Be sure to include days immediately following a rating change and subdivided days.
2. Check shift application against statement made in station analysis.
3. Check discharges during footnoted periods for reasonableness. Estimates are generally carried to one less significant figure.
4. Ice-affected periods are "black-lined" to show no stage-discharge relation.
5. Check "a" days for possible range in stage.
6. Check discharges at points of rating change for continuity.
7. Check discharge for October 1 against discharge for September 30 of previous water year for continuity.
8. Monthly means should lie between monthly extremes; yearly mean should lie between yearly extremes and also between extremes of monthly means.
9. Million cubic meters should be roughly three times the mean.
10. Check peak listing against daily discharge. Peaks should be higher.
11. Check momentary maximum against peak listing and for shift application.

12. Check momentary minimum against daily discharge. If it is the same then designate it as "minimum daily discharge". Check for application of shift.

13. Check form for completeness: footnotes, remarks, headings, etc.

GENERAL INFORMATION

The following sections do not bear directly on the computation of streamflow records but will be useful in keeping the records consistent and in troubleshooting some of the more common irregularities. The inexperienced person doesn't realize how much trouble can be caused at future times by inconsistency of names, significant figures, classification, numbering system, etc. Twenty years or more from now hydrologists will be making use of the data computed today. If there are inconsistencies or the data are computed to differing standards, bias will be introduced into the future computations.

Significant Figures

In the computation of streamflow records, a standard number of significant figures are used on the various forms to assure uniformity and to avoid carrying the computations to a greater degree of refinement than is warranted by the base data. The following instructions will help the technician to understand significant figures and will define the number of significant figures to be used in the computations.

1. Significant figures.--The digits 1, 2, . . . 9 are always significant, but 0 (zero) may or may not be significant. Zeros to the left of all other digits are never significant (as in 0.0345 which has only three significant figures). Zeros between other digits are always significant (as in 3005 which has four significant figures). Zeros to the right of all other digits are significant if any of them are also to the right of the decimal point (as in 40.0 and 0.0230, each having three significant figures).

   Examples: (The significant figures are underlined)

   135.0 (four significant figures)

   1350 (three significant figures)

   0.003500 (four significant figures)

   13.050 (five significant figures)

   10,002.00 (seven significant figures)

   100,000 (one significant figure)

2. <u>Rounding Off.</u>--To round off a number to three significant figures all digits to the right of the third digit are discarded or dropped. If the first digit on the left of the discarded, or dropped, number is less than half a unit, leave the third digit of the significant figure unchanged; if the discarded number is greater than half a unit, add 1 to the third digit of the significant figure. If the discarded number is exactly half a unit, leave the third digit of the significant figure unchanged if it is an even number, but increase it by 1 if it is an odd number.

Examples: (All rounded to three significant figures)

38.5452	rounds off to 38.5
0.04899608	rounds off to 0.0490
1.286500	rounds off to 1.29
1.28500	rounds off to 1.28
268,174	rounds off to 268,000

If, when making interpolations by use of tables, there is a choice between two successive digits, the even one is to be used.

In general, no increase in the accuracy of a result computed by multiplication and division is attained by using more significant figures than is contained in the least accurate figure.

Examples:

12.3 x 3.41719 round to 12.3 x 3.42

12.3492 x 1.60 round to 12.3 x 1.60 (same rounding for division)

In addition and subtraction, accuracy to a certain number of decimal places is appropriate. Before adding or subtracting, round off the given numbers so that not more than one column at the right is broken. Add or subtract, and then round the sum so that its last digit comes in the last unbroken column.

Example:

Given	Round off to and add
0.4256	0.43
3.482	3.48
49.6	49.6
	53.51 (round to 53.5)

In general, streamflow records are computed to three or four significant figures. Accuracy will be well within one percent when all but the first three significant figures are dropped. For example, when the number 10,256 is rounded to 10,300, the value is increased by 44, which is only 0.4 percent of the original number 10,256.

3. Significant figures used on forms:

   Gage heights on discharge measurement notes, list of discharge measurements form, and gage height and discharge computation form.

   Example:

To nearest 0.005 meters below 10.0 meters, to 0.01 meters at and above 10.0 meters.	0.355 3.355 13.55

Discharge, area and velocity on discharge measurement notes.

Example:

Three digits to the right	0.064
of the decimal point below	0.355
10.00, four significant	3.355
figures at and above 10.00	13.35
	133.5

Discharge, area and velocity on list of discharge measurements form.

Example:

Three digits to the right	0.035
of the decimal point below	0.355
1.00, three significant	3.55
figures at and above 1.00	33.5
	335
	3350

Discharge on rating table, and daily discharge and maximum and minimum discharges on gage height and discharge computation form.

Example:

Three digits to the right	0.035
of the decimal point below	0.355
1.00, three significant	3.55
figures at and above 1.00	33.5
	335

Mean discharge, monthly and annual on gage height and discharge computation form.

Example:

Four significant figures except	0.035
no more than three digits to	.354
the right of the decimal point.	3.354
	33.35
	333.5

For monthly mean, divide monthly total by days in month. For annual mean, divide annual total by days in year. (Be careful when computing annual mean for a "leap" year. Calendar year mean and water year mean will not be computed from same number of days in year.)

Gaging Station Classification

All gaging stations for which records of daily gage height and daily discharge will be computed should be classified under a system that indicates (1) the purpose for which the gage was installed and (2) whether the installation is intended to be permanent or temporary.

Under (1) above three categories are generally sufficient to denote the purpose:

a. Mainstem - this category would be used for stations on the major rivers to give information on the hydrology between reaches of the river.

b. Areal - this category would be used for stations where information on the hydrology of specific areas is desired.

c. Water Management - this category would be used for stations where information on discharge is needed for management of reservoirs, irrigation systems, etc.

Occasionally, a fourth category is used to denote benchmark or vigil network stations. Benchmark stations are for the purpose of determining the effects of man's activities on the streamflow regimen; vigil network stations are for the purpose of observing the long-term changes in the principal hydrologic and landscape features of a basin.

Under (2) above two categories are sufficient to denote whether the gage is intended to be permanent or temporary:

a. Primary - for stations so located that the data cannot be obtained in any other manner such as by correlation, the summation of upstream stations, etc.

b. Secondary - for stations in areas of short-term interest or which correlate within acceptable limits with a primary station after a period of concurrent operation, usually about 5 years.

In many cases gaging stations have more than a single purpose. In this situation the classification which applies to the purpose having the longest time span would be used. For example, the gaging station on the Helmand River above Kajakai Reservoir at Dehraout has several purposes: (1) It measures all discharge from the basin at that point, (2) the inflow to the river reach between Ghizao and Dehraout can be computed by subtracting the flow at Ghizao from that at Dehraout, (3) the records are used in management of the reservoir and downstream irrigation systems, and (4) the station can be used for flood forecasting.

Because it is possible to conceive that at some future time the record will no longer be needed for either water management or flood forecasting, these purposes have a relatively short time span. Therefore, this station would be assigned the classification of "Mainstream Primary" because (1) there is an upstream station to constitute a reach of river (mainstem), and (2) although it might be possible to measure the discharge at that point by correlation with the station at Ghizao, the much longer length of record at Dehraout would make it the independent variable for correlation purposes (primary).

Another example of selecting the proper classification is given by the gaging station on the Helmand River below Kajakai Reservoir. Here it would depend on how the data appears in final publication. If, as at present, the data is published unadjusted for the effects of Kajakai Reservoir, then the proper classification would be "Water Management". If the data is published adjusted for the effects of the reservoir, then the classification would be "Mainstem Primary" or "Mainstem Secondary" because it now represents natural flow and water management would be subordinate. It also represents the downstream point in a reach of river. The "Primary" or "Secondary" would depend on the degree of correlation with the station above the reservoir or, even if an acceptable correlation exists, there may be other need for continuing the record at this point.

Gaging station classification may be changed. For example, before the gaging station was built at Ghizao the classification for the station above the reservoir at Dehraout was "Areal" because it was the only station to measure all of the discharge from the Helmand basin above that point. Also, because it is on the main river, it has been and will continue to be the primary station for correlation with tributary rivers such as the Kaj or Tirin and therefore would never be designated as "Secondary".

The above discussion pertains to gaging stations for which records of daily gage height and daily discharge will be computed. There are other types of gaging stations that serve special purposes. These are:

a. Partial record stations - these are used to determine the discharge during critically high- or low-flow periods. For example, an irrigation system is more dependent on minimum flows that occur during the growing season than on average or high flows; a flood-control project would require information on flows large enough to cause flooding; an industry might operate only during the part of the year when raw products are available. A partial record station gives the same data as a regular gaging station while it is operating, but it operates only during the time that the river is at the critical stage for the information desired.

b. Crest-stage gage - these are used to determine the maximum stage that has occurred since the previous visit or, when two or more are installed in a reach of river, the slope of the river at maximum stage. These are used at sites where the only interest is in maximum stages or discharges. For example, a highway project would be interested in maximum stages to know how high to build a bridge above the streambed and would also be interested in maximum discharges to know how large an opening to make; an industrial or residential area would be interested in the stage above which flooding occurs but would not be concerned with the amount of discharge that causes a flood; in remote areas inaccessible during periods of high water, two or more crest stage gages establish the slope of the river profile and from this indirect measurements of the discharge that occurred during the flood can be made when the roads are again passable.

c. Reservoir stations - these are used to determine the reservoir contents or surface area at any elevation of the reservoir surface. In planning and operating, it is important to know the volume of water impounded because of possible changes in cropping practices, hydropower generation, and other industrial or agricultural uses that may be necessary or desirable because of the amount of water stored.

d. Stage stations - these are used for determining the elevation of a river above a reference point for forecasting flood crests and for navigation.

The above classifications will be sufficient for all proposed gaging stations in Afghanistan. To simplify identification of the classification the following abbreviations should be used:

Areal primary	AP
Mainstem primary	MP
Areal secondary	AS
Mainstem secondary	MS
Water Management	WM
Partial record	PR
Stage	SS
Crest stage	CS
Reservoir	RS
Bench mark	BM
Vigil network	VN

Gaging Station Numbering System

Each river system will be assigned a number consisting of three groups of digits separated by decimal points (00.0000.00). The first group of digits will refer to the river system, the second group to the tributary order (1st order, 2nd order, etc.), and the third group to the gaging station location and classification. Numbers for the second and third groups of digits will be assigned in downstream order with the tributary or gaging station nearest the mouth receiving the highest number.

Classification of gaging stations and the digit assigned for that classification are:

Areal Primary	AP	0
Mainstem Primary	MP	1
Areal Secondary	AS	2
Mainstem Secondary	MS	3
Water Management	WM	4
Partial Record	PR	5
Stage	SS	6
Crest Stage	CS	7
Reservoir	RS	8
Bench Mark or Vigil Network	BM or VN	9

When assigning numbers for the second group of digits and the first digit of the third group, use numbers that show the approximate location in relation to the preceding number. For example, assume an areal secondary gaging station to be built near the mouth of the Salang River:

Basin:	Indus River, arbitrarily assigned digit 10.
River:	Kabul, stream order 4th, assigned digit 3, showing it joins the Indus River about one-third of the distance from the source to the mouth.
River:	Panshir, stream order 3rd, assigned digit 4.
Stream:	Ghorband, stream order 2nd, assigned digit 6.
Tributary:	Salang, stream order 1st, assigned digit 9.
Gaging station:	Near mouth, assigned digit 9.
Classification:	Areal secondary, assigned digit 2.

This gage would be assigned the number 10.3469.92. The attached list contains a suggested numbering system for all basins, rivers, and tributaries in Afghanistan that appear to be of hydrologic importance or that may be suitable for future development.

Suggested numbering system for rivers and streams

1.0000	Oxus (Amu Darya, Darya Panje, Pamir)
1.1000	Wakhan
1.2000	Kokcha
1.2300	Anjoman
1.2500	Warduch
1.2590	Zardew
1.2700	Unnamed
1.2800	Mashed
1.3000	Kunduz (Surkhab, Bamyan)
1.3100	Unnamed
1.3200	Jaozar
1.3500	Andarab
1.3700	Unnamed
1.3900	Khanabad
1.3960	Farkhar
1.3970	Bangi
1.3978	Unnamed
1.3980	Unnamed
1.4000	Tashkurgan (Kholem)
1.4300	Unnamed
1.4600	Unnamed
1.4800	Unnamed
1.5000	Balkh
1.5100	Unnamed
1.5300	Unnamed
1.5700	Darya Yusaf
1.5740	Unnamed
1.6000	Sarepul
1.6200	Unnamed
1.6400	Sorab
1.6420	Unnamed
1.6480	Unnamed
1.7000	Shirin Tagao
1.7400	Unnamed
1.7600	Qaizar
1.7620	Unnamed
1.7650	Unnamed
1.7670	Unnamed
1.7680	Unnamed

2.0000	Murghab
2.1000	Unnamed
2.2000	Unnamed
2.3000	Unnamed
2.4000	Unnamed
2.5000	Unnamed
2.6000	Unnamed
2.7000	Unnamed
2.8000	Chickaktu
2.8500	Unnamed
2.8600	Unnamed
2.9000	Kulari
2.9200	Unnamed
2.9300	Unnamed
2.9400	Unnamed
2.9600	Unnamed
2.10000	Kushk
2.10400	Unnamed
2.10500	Unnamed
2.10600	Unnamed
2.10700	Qezel
2.10750	Unnamed
2.10758	Unnamed
3.0000	Hari
3.1000	Unnamed
3.2000	Lal
3.4000	Shir Khaj
3.5000	Kowgon
3.5200	Dahuk
3.5300	Gaugrah
3.5600	South Fork Kowgon
3.7000	Karookh
3.8000	Sinjou
3.9000	Unnamed
4.0000	Adraskand
4.2000	Gaz
4.4000	Unnamed
4.7000	Anardarra
4.9000	Unnamed
5.0000	Farah
5.4000	Ghor
5.5000	Malman
5.6000	Wakhal
6.0000	Khuspas Wash
7.0000	Khash

8.0000	Dor Wash
9.0000	Helmand
9.1000	Syasang
9.2000	Markhana
9.3000	Panjao
9.4000	Sang-i-Takh
9.4500	Unnamed
9.5000	Kaj
9.5300	Unnamed
9.5600	Unnamed
9.5900	Unnamed
9.6000	Tirin
9.6500	Unnamed
9.6700	Morcha
9.6800	Chora
9.7000	Musa Qala
9.7500	Unnamed
9.7600	Unnamed
9.8000	Sangin Wash
9.10000	Arghandab
9.10300	Unnamed
9.10400	Wayan Wash
9.10500	Unnamed
9.10600	Shah Joi Wash
9.10800	Dori
9.10810	Kadani
9.10815	Unnamed
9.10830	Arghastan
9.10833	Unnamed
9.10835	Unnamed
9.10836	Lora
9.108361	Nahar
9.1083612	Park
9.108362	Ghazni
9.1083622	Unnamed
9.1083624	Jilga
9.10836246	Paltu
9.10837	Unnamed
9.10838	Unnamed
9.10840	Tarnak
9.10843	Ali Zar
9.108435	Unnamed
9.10900	Kushki-i-Nakhud
9.11000	Marja Wash
9.12000	Godari Wash

10.0000 Indus
10.3000   Kabul
10.3100   Paghman
10.3180   Qargha
10.3200   Logar
10.3240   Unnamed
10.3250   Unnamed
10.3300   Ghazi
10.3400   Panshir
10.3460   Ghorband
10.3465   Unnamed
10.3469   Salang
10.3500   Unnamed
10.3600   Laghman
10.3650   Unnamed
10.3680   Alisang
10.3700   Unnamed
10.3800   Kunar
10.3850   Landai
10.3870   Pesh
10.5000   Khoram
10.5400   Kaitu
10.5420   Tongi
10.5426   Unnamed
10.5440   Unnamed
10.5460   Unnamed
10.5470   Matun
10.5480   Zambar
10.5900   Margha
10.5920   Mastoi
10.6000   Gumal
10.6100   Little Gumal

11.0000 Pishin Lora

River Names

Quite often there is confusion over the proper name for a river or tributary because there is no governing body that determines the proper name. The local name may be different from that appearing on maps, and different map series often show different names. Until such time as a proper Board of Geographical Names is organized, a system must be adopted that will identify a river or tributary by both local and map name, and by any other name by which it is known.

The mainstem of a river is defined as either the longest stretch of channel from the mouth to the headwaters or as the channel carrying the largest discharge regardless of length. A tributary is defined as any channel that discharges into the mainstem or another tributary.

To be consistent, the mainstem of a river should carry the same name for its entire length regardless of local usage; but because of uncertainty that would exist by strict adherence to this rule it must be modified to show local names also. For example, the Kunduz River is known locally by that name from its mouth to some indefinite point between Kunduz and Baghlan, as the Surkhab River in the vicinity of Pulikhumri, and as the Bamian River in the vicinity of Doab. To properly identify this river it should be known as the Kunduz River for its entire length from the mouth to the headwaters above Bamian and the local name shown in parentheses. In other words, the gaging station at Pulikhumri would be named Kunduz (Surkhab) River near Pulikhumri, the gaging station at Doab would be named Kunduz (Bamian) River at Doab, etc.

At times there may be more than one local name. In this circumstance, the local name most often used should be shown in parentheses immediately after the proper name and the remaining names shown under "remarks" on whatever form is being used. For example, in a Station Analysis under remarks would appear the statement "Also known as ______________ River."

Names of rivers should be taken from the official base map of Afghanistan wherever possible. Conversely, the WSSA should be consulted by the Cartographic Institute whenever uncertainty of river names occurs.

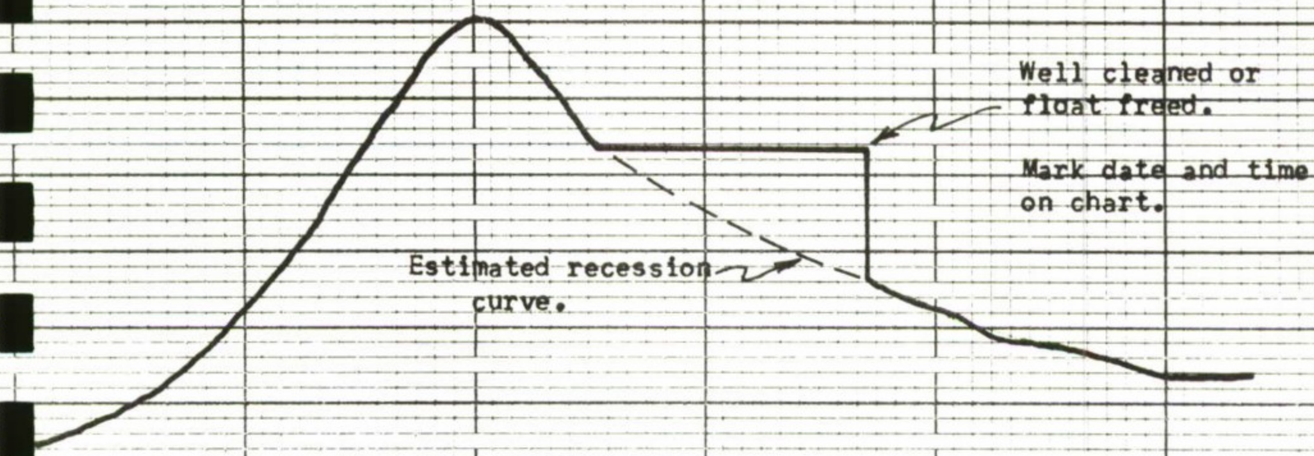
Causes and Corrections of Unusual Trace Configurations

Unusual recorder chart trace configurations result from the automatic water-stage recorder functioning under abnormal conditions and can result from malfunctions of the recorder, stilling well, and intakes, from erratic behavior of the stream and control, and from variations in atmospheric conditions. The unusual trace caused by malfunctions of the recorder, stilling well, and intakes are mechanical malfunctions and can be corrected. The unusual trace caused by behavior of the stream or control and from atmospheric conditions generally cannot be corrected but the engineer should be familiar with these trace patterns so that he can form a mental image of past events by looking at the recorder chart. Figures 15 to 27 show representative trace patterns and their causes and corrections (if any).

In addition to the mechanical malfunctions illustrated, there are others that occur but do not necessarily give a distinctive trace pattern. These are:

1. Reversal "diamond" jammed.--If the drive chain pin cannot move freely through the diamond it can affect the trace in two ways: (a) on a falling stage the pin will remain jammed and not allow the float to recede with the stage. This will show on the trace as a horizontal line at or near the reversal point. When the stage falls until the weight of the float exceeds the bending point of the drive chain pin, the float will fall instantaneously

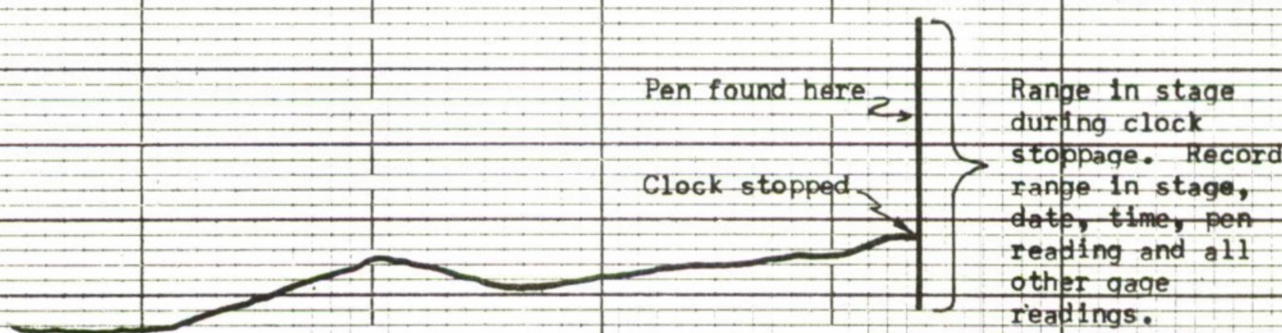
RECORDER OR STILLING WELL MALFUNCTIONS:



Cause: Stilling well silted, intakes plugged, or float hung on obstruction.

Correction: Clean well or intakes or remove float obstruction.

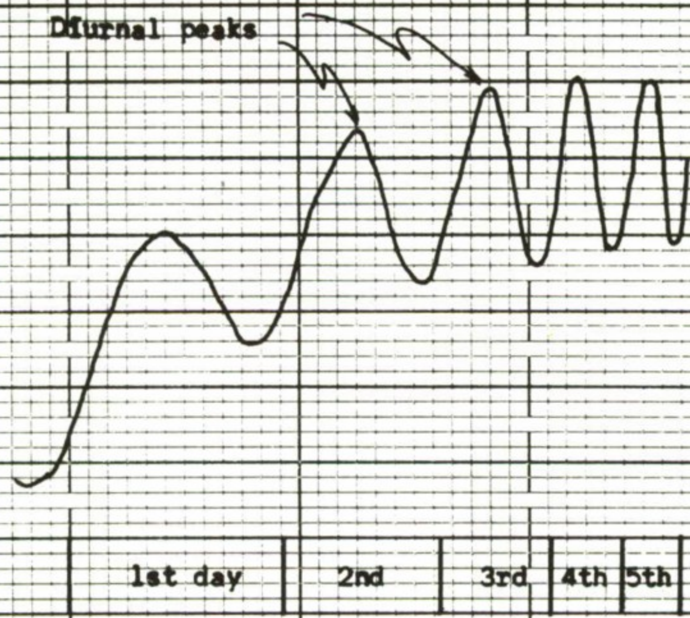
Figure 15.



Cause: Clock stopped.

Correction: Replace clock or add more weight if spare clock unavailable. If stopped because weight is on bottom, install sheaves and additional weights to increase running time.

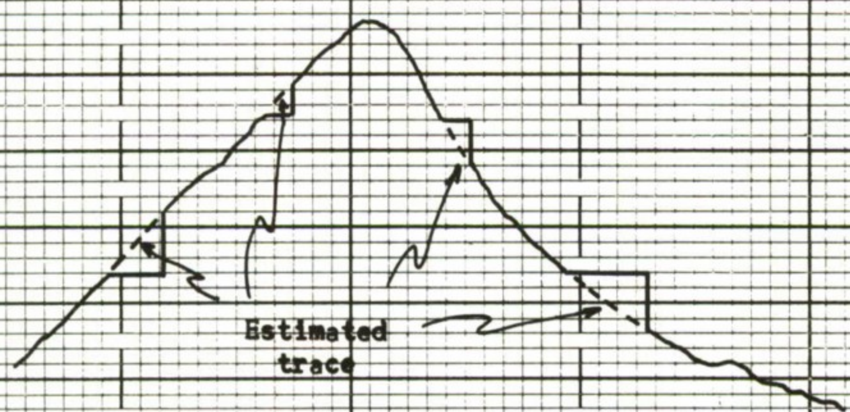
Figure 16.



Cause: Clutch slipping or takeup roll clip not tight.

Correction: Adjust clutch or tighten takeup roll clip.

Figure 17.



Cause: Float, tape, or counterweight temporarily hung on obstruction in well or on instrument shelf, or thumb screws on float wheel not tight.

Correction: Find and remove obstruction or tighten thumb screws.

Figure 18.

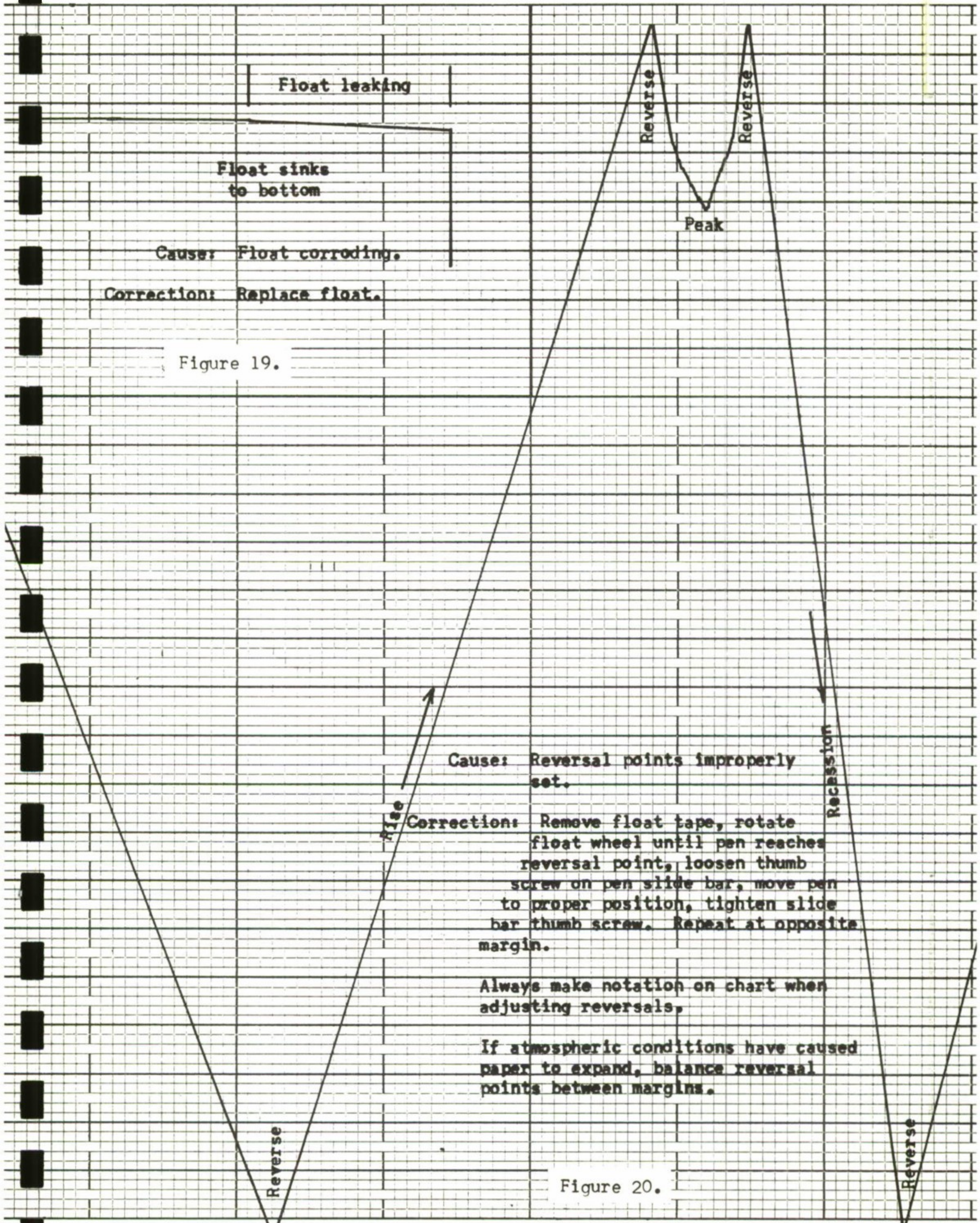
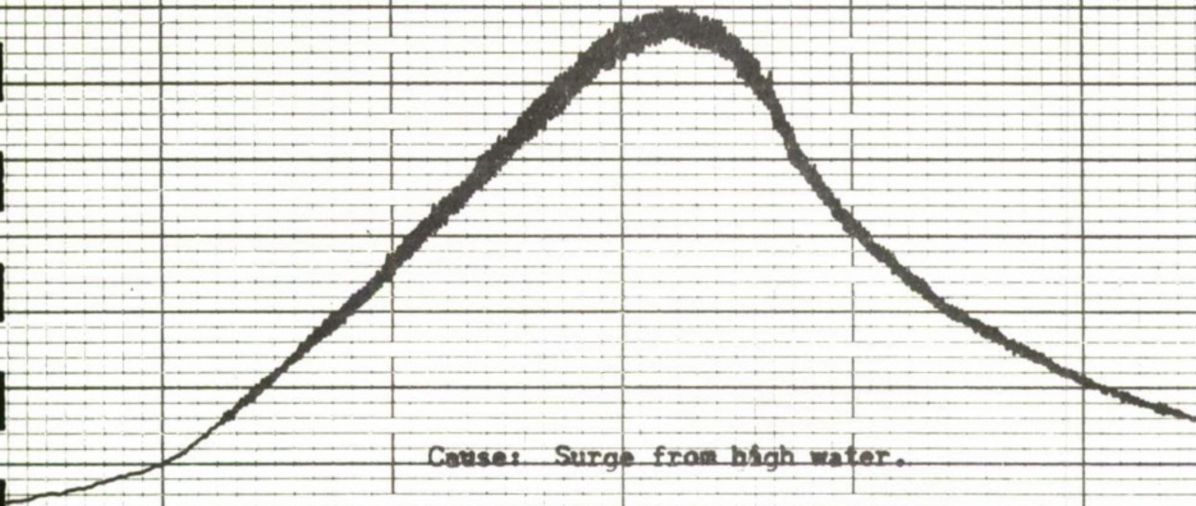


Figure 19.

Figure 20.

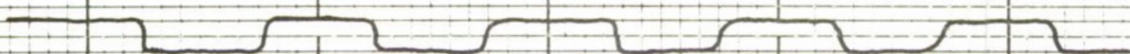
STREAMFLOW OR ATMOSPHERIC CONDITIONS:



Cause: Surge from high water.

Correction: Use static tubes or decrease size and number of openings in well.

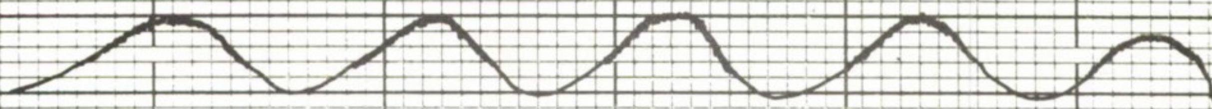
Figure 21.



Cause: Regulation for irrigation or other cause upstream.

Correction: None. Represents true flow.

Figure 22.



Cause: Diurnal fluctuation from snowmelt upstream.

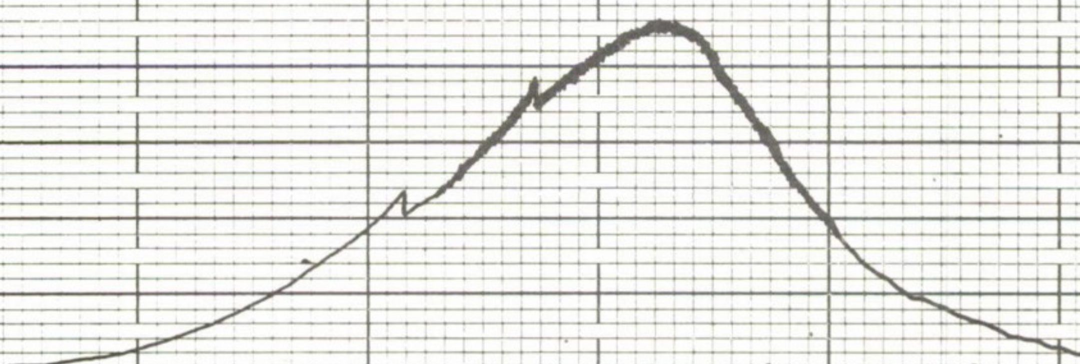
Correction: None. Represents true flow.

Figure 23.

Cause: Diurnal fluctuation from evapotranspiration.

Correction: None. Represents true flow.

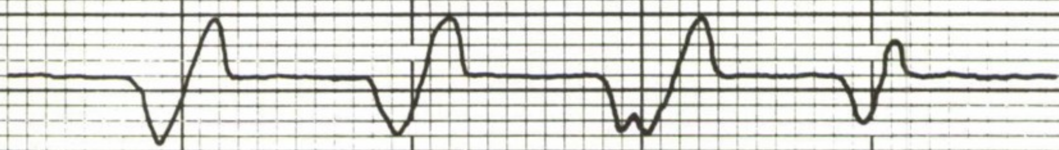
Figure 24.



Cause: Temporary obstruction on control.

Correction: None unless obstruction remains. Remove obstruction <u>after</u> making current meter measurement.

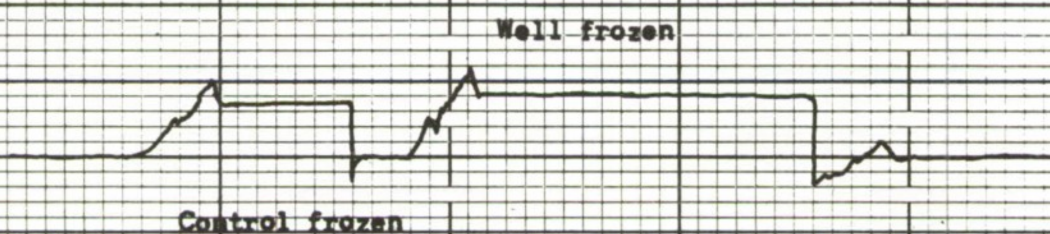
Figure 25.



Cause: Upstream ice affect. Alternate thawing and freezing at higher altitude.

Correction: None. Represents true flow past gage and generally balances out to where mean is the same as if variations did not occur.

Figure 26.



Cause: Freezing of control and stilling well.

Correction: Install oil tube to prevent well freezing. No correction for control freezing.

NO STAGE-DISCHARGE RELATION
UNDER THIS CONDITION.

Figure 27.

to the stilling well water surface. This will cause a vertical line on the trace. Any stage recorded during or after the time the pin jams (even after the float falls to the water surface) will be in error because the pin no longer contacts the pen carriage properly; (b) on a rising stage the pen carriage will not move if the chain pin jams. This will also "freeze" the float wheel allowing slack to accumulate in the float tape. The trace will show a horizontal line until the stage recedes to the point where the pin originally jammed. The pin may or may not back out of the jammed position and resume a normal trace. Also, the slack in the float tape may cause the tape to come out of the splines on the float wheel resulting in an erroneous trace even if the pin frees itself. To correct, adjust the drive chain pin and/or the diamond until pin runs smoothly through reversal.

2. <u>Tape off splines.</u>--This is usually caused by a kink in the float tape from careless handling. The float wheel splines and the float tape holes are precision matched. Any kinking shortens the distance between adjacent holes and the tape will come out of the splines. To correct, straighten out kink or replace with new tape.

   Another cause of tape coming off splines is rapid and excessive surge in the well. To correct, install static tubes on pipe intakes or close off excessive holes in a well with trench intake.

It is not always possible to detect this trouble from the pen trace. Many times the tape will reengage the splines at the correct point. If there are large differences between trace readings and observer's readings, inspect the tape for kinks in the range of disagreement. Also, if the visiting engineer notes a large difference between pen trace and float tape gage readings, he should see if the pen can be brought into agreement with the float tape gage by moving the splines to engage the tape in an adjacent hole.

3. Pen adjusting screws loose or tight.--There are three pen adjustment screws: One on each side of the lucite ink reservoir and one on the pen slide bar yoke. If the reservoir screws are too tight they restrict the vertical movement of the pen and can result in a loss of trace; if they are too loose, a slight deviation from the true reading may result or the pen may fall out of the yoke. If the screw on the slide bar yoke is loose, a large error may result as the pen yoke slides along the bar.

The correct adjustment is for the reservoir screws to be just tight enough to allow free vertical movement of the pen without horizontal movement, and the slide bar yoke screw to be tight.

Never adjust pen to correct reversal position by twisting the pen capillary tube in lucite reservoir. Adjust by moving the yoke on slide bar.

4. Clutch too tight.--A tight clutch stretches the chart paper and results in the same trace appearance as if the clock were running slow. The correct adjustment is to feel resistance on the take-up roll when moved by hand. It should not be so tight that it takes considerable force to move it nor so loose that it won't overcome the inertia of the idler rollers or friction of the paper across the writing platform.

5. Paper crooked or loose on take-up roll.--This is the result of negligence when reclamping the paper on the take-up roll after removal of a chart section. This is easily detected by looking at the chart on the take-up roll before removal. When the paper appears to be crooked or loose, remove the float tape from the float wheel and mark reversal points before removing chart from take-up roll. This will allow calculation of the gage-height error caused by the paper running crooked or being loose.

6. Ink on rollers.--This is caused by overfilling the ink reservoir. The reservoir should never be more than half full. When the reservoir is too full, atmospheric conditions will cause it to overflow, spilling ink on

the chart. This in turn soaks through the chart paper onto the rollers. To correct an overfull ink reservoir, remove it from the yoke by loosening adjustment screws on one or both sides, wash in clean water, clean the pen capillary tube with a pen cleaning wire, refill reservoir to proper level, start ink flow by gently blowing on reservoir opening until drop of ink appears at tip of capillary tube, and reinstall on yoke. Clean rollers with clean cloth dampened in clean water.

7. Miscellaneous.--Many minor unaccountable variations in the recorder trace can be traced to natural phenomena or disturbances by man or animals. For example, an earthquake will cause a minor jog in the trace, the added weight of a large frog crawling on the float will cause an apparent drop in gage height until he jumps off and the float returns to its normal position, swimmers or a large number of animals in the gage pool will cause minor fluctuations of the trace, a strong wind causing ripples on the gage pool may be reflected inside the well, ice forming on the gage pool may result in an irregular trace as it breaks up and moves out over the control the next morning, "mud-dobber" wasps may build nests between the float wheel and recorder case and stop the motion of the float wheel.

The unusual recorder chart trace configurations listed above and on the accompanying illustrations are the ones the engineer is most likely to encounter. It is by no means an exhaustive list because we are constantly finding unusual trace configurations that cannot be traced to any of these causes. The engineer who is constantly alert for the unusual when he visits a station can eliminate most of the causes of these unusual traces.

Recorder Clock Stoppage

The clock used in the Stevens A35 automatic water-stage recorder is a high-grade, 7-jeweled Chelsea marine movement housed in a sealed case. It is the driving and speed regulating mechanism for the time element of the recorder. The clock is connected by suitable gearing to the chart drum and take-up roller by a universal driving bar outside the clock case which engages the pins on the time scale gears on the recorder. The clock is attached to the recorder base by two knurled mounting screws, and the clock is easily attached or removed without tools. The clock mechanism is driven either by weights (which vary in size according to the time scale selected) or by a negator-spring motor. Most recorders in use in Afghanistan are equipped with weight-driven clocks. Negator-spring motors are used only where space restrictions would prohibit use of a weight-driven clock. The following are the most common causes of recorder clock stoppage or malfunctioning:

Weight-driven clocks

1. An accumulation of dust, dirt, or moisture in the recorder or clock will cause the clock to stop or run slow or fast (usually slow). Do not attempt field repairs. Replace the clock and bring it to the office for repair.
2. The clock weight cable binding or sticking because of too much cable on drum or improper winding will cause clock stoppage. To correct, detach the clock, release

drive mechanism brake, and unwind the clock cable past point of trouble. If the cable is too long, cut to correct length and rewind on drum properly. If the cable is frayed or badly kinked, replace with new cable. The cable should be guided with free hand while winding to assure that cable does not overlap on itself.

Important: When releasing the drive mechanism brake, be sure to hold cable drum by hand. Otherwise the clock weight will immediately plunge to the bottom of the well or to the end of the cable.

3. The inner knurled clock-mounting screw being loose and not exerting enough pressure to release the brake on drive mechanism will cause clock stoppage. To correct, simply tighten the knurled screw to where it releases brake.

4. The clock weight resting on an obstruction or on the bottom of the well will cause clock stoppage. To correct, remove the obstruction or reposition recorder in shelter and rewind clock.

Negator-spring driven clocks

1. The negator spring wound beyond red-marked stopping point will bind. To correct, detach the clock, release the drive mechanism brake, and allow spring to rewind on the take-up drum.

Important: Always hold hand on both drums so spring cannot release freely. Reinstall clock and wind the spring to correct position.

2. The negator spring not centered on the drums will cause binding on sides. To correct, straighten with your fingers or a metal straight edge.

Important: Always check centering alignment on the take-up drum after winding the negator spring.

Both weight-driven and negator-spring driven clocks will be affected by an overtight clutch. If no reason can be found for clock stoppage, check tightness of the clutch. To correct, bend the clutch fingers inward to loosen clutch.

Important factors

1. Always use one hand to guide cable on drum evenly when winding clock.
2. Always wind the clock weight or negator spring slowly and evenly. Any jerky movement puts unusual strain on the clock mechanism.
3. Keep inside of recorder clean and free of dust.
4. Conduct torque tests on each clock and recorder at least twice a year. Replace any clock that does not run at the recorder torque output. Clean and oil any recorder that delivers less than 35 inch-ounces of torque and recheck.
5. Remove winding crank and replace dust cap.
6. Do not wind weight so high that clock weight spring contacts instrument shelf.
7. Always be sure to push chart feed-roll clutch rod in

before closing recorder lid. Lid will not close properly with clutch rod out.

All clocks are factory set to run correctly at a certain recorder torque output. The torque output of most recorders is usually more or less than this amount after the recorder has been in service for a while and this will result in a clock running slower or faster than normal time. A clock can be adjusted in the field by removing the clock front cover plate and turning the notched speed control screw in the proper direction. Generally, only a small adjustment is necessary.

Atmospheric conditions can also cause a clock to vary from normal time. Extreme cold temperatures make the oil in the recorder and clock more viscous. This results in the recorder putting out less torque and the clock requiring more torque to run at normal speed. This can be overcome to some extent by adding to the clock weight. In areas subject to sub-freezing temperatures, add one or two more pounds (0.5 or 1.0 kilos) to the clock weight in the fall and remove the additional weight in the spring. Do not add more than two pounds (one kilo) as this will put too much strain on the recorder mechanism.

RECOMMENDED FORMS

The U. S. Geological Survey has developed a number of forms for use in the computation of basic streamflow records. Most of these forms are made a part of the permanent station record. In the pocket on the inside back cover of this manual is a sample of each of the forms used as well as a few forms needed for supplemental data such as station descriptions, drainage area computations, monthly summaries, etc. The Water and Soil Survey Department should adopt these forms for use in Afghanistan with modification of the heading and the units changed to the metric system.

The following forms are in the pocket:

9-207	List of Discharge Measurements
9-210a	Rating Table
9-279	Rating Curve (Rectangular)
9-279G	Rating Curve (Logarithmic)
9-279L	Rating Curve (Logarithmic)
9-192B	Daily Gage Heights and Discharges
9-284	Hydrograph (Logarithmic)
9-197	Station Description
9-211c	Daily Discharge
9-220c	Monthly and Annual Discharge
9-258	Drainage Area Computation
9-258A	Drainage Area Tabulation
9-230	Computation Sheet

INTRODUCTION TO ADVANCED HYDROLOGY

Quite often the new technician wonders why the computation of basic streamflow records is so important or what happens to the material after the computations are finished and published. It usually happens that a hydraulic engineer or technician isn't exposed to the practical use of this material until he has acquired a sound background in the collection and computation of the basic data. To the beginner, the never-ending repetition of field collection and office computation often gets monotonous and boring if he can't understand how it will be used.

In Afghanistan, as in most parts of the world, the historic use of water has been largely as dictated by nature. But with the increase of population and the influx of industry careful accounting and usage will have to be made if the available water is to do the job these changes and advancements will demand. With increasing frequency the engineers and technicians of the Water and Soil Survey Authority will be asked such questions as:

> How much water is available for storage from this river at this point? Is there enough water to meet an irrigation requirement of X cubic meters per year?
>
> How much water will have to be stored for a hydropower demand of X cubic meters per second of flow? How often, on the average, will there be a flow less than X cumecs?

How large an opening will there have to be in a bridge at this point to pass a 50-year flood safely? What will be the magnitude, in stage and discharge, of the 50-year flood?

A factory wants to locate at this site. How many days a year, on the average, will the plant have to shut down because the flow of the river drops below the requirement for processing the raw material and safely disposing of wastes? How much storage would be required to keep the plant operating the entire year?

A town wants to improve its water supply as well as install a sewage system. Where is a source of water, what is its quality, and how much treatment will the sewage require before the effluent is released?

These are typical questions asked the practicing hydraulic engineer or hydrologist, and without basic streamflow data, they cannot be answered with any degree of reliability. It is true that over the years hydrologists have developed methods for estimating runoff from precipitation records, but estimates based on these methods are mostly just educated guesses and generally apply only to humid climates. In Afghanistan, where the precipitation pattern is so erratic and there is a scarcity of precipitation records, rainfall-runoff correlations are dangerous unless verified by some streamflow data. This is why we have been interested in building up a basic streamgaging network so quickly.

To answer questions such as those listed above, many hydrologic tools have been developed ranging from simple tabulations to complex mathematical relations. Examples of a few of these have been taken from reports done by the author while on river basin investigations in the United States.

Mass curves.--Mass curves are the cumulative values of a variable plotted against time (simple or single mass curves), against the cumulative values of a second variable (double mass curves), or with a constant value removed (residual mass curves).

A simple mass curve (figure 28) is used to solve some storage problems. The maximum ordinate between the mass curve of runoff and the mass curve of required discharge is the storage required to maintain the discharge. The problem can be turned around to answer how much discharge can be obtained from a given storage.

A double mass curve (figure 29) will indicate the consistency of one variable in relation to another. Any break in the slope of the line of relation indicates a change in one of the variables as it affects the other.

A residual mass curve (figure 30) magnifies the breaks in slope that occur in simple or double mass curves and may reveal changes in the relation undetected in the other types.

Flow-duration curves.--These are cumulative frequency curves (figure 31) that show the percentage of total time the flow equaled or exceeded a given discharge without regard to sequence of events. These are used for many purposes: The shape of the curve indicates the drainage basin characteristics, it is used to predict the availability of future flows, the variation of flow is shown, the area under the curve is proportional to the average yield, and the streamflow characteristics can be compared with other streams.

Frequency curves.--These express the expected frequency of occurrence of some event of given magnitude such as floods or low flows. Figure 32 illustrates a low flow frequency curve.

Simple curves of relation can be used to express many things and are quite useful. Figure 33 illustrates a simple relation between measured discharge at various points in the basin and the mean discharge at a gaging station. Figure 34 illustrates the relation between regulated discharge and storage requirements at various points in a basin.

Quite often tabulations of data are quite useful. Figure 35 shows the tabulation of the duration data used to plot the duration curve shown in figure 31. While the curve shows the percentage of total time a specific discharge was equaled or exceeded, the table can be used to show that in certain years the flow did or did not fall below or exceed a specified discharge.

Figure 36 illustrates a tabulation of the highest and lowest mean discharges for a specified number of consecutive days during each water or climatic year. The low-flow table is especially meaningful. It shows for example, that for 6 years out of 30 there will be no flow for 30 consecutive days, for 3 years out of 30 there will be no flow for 60 consecutive days, and that it has never dried up completely for 90 consecutive days during the period of record.

The above examples are but a few of the uses for the basic data. The important thing for the beginner to realize is that all of these advanced computations rely on the basic data. If the basic data is inaccurate, all other computations based on it will also be inaccurate.

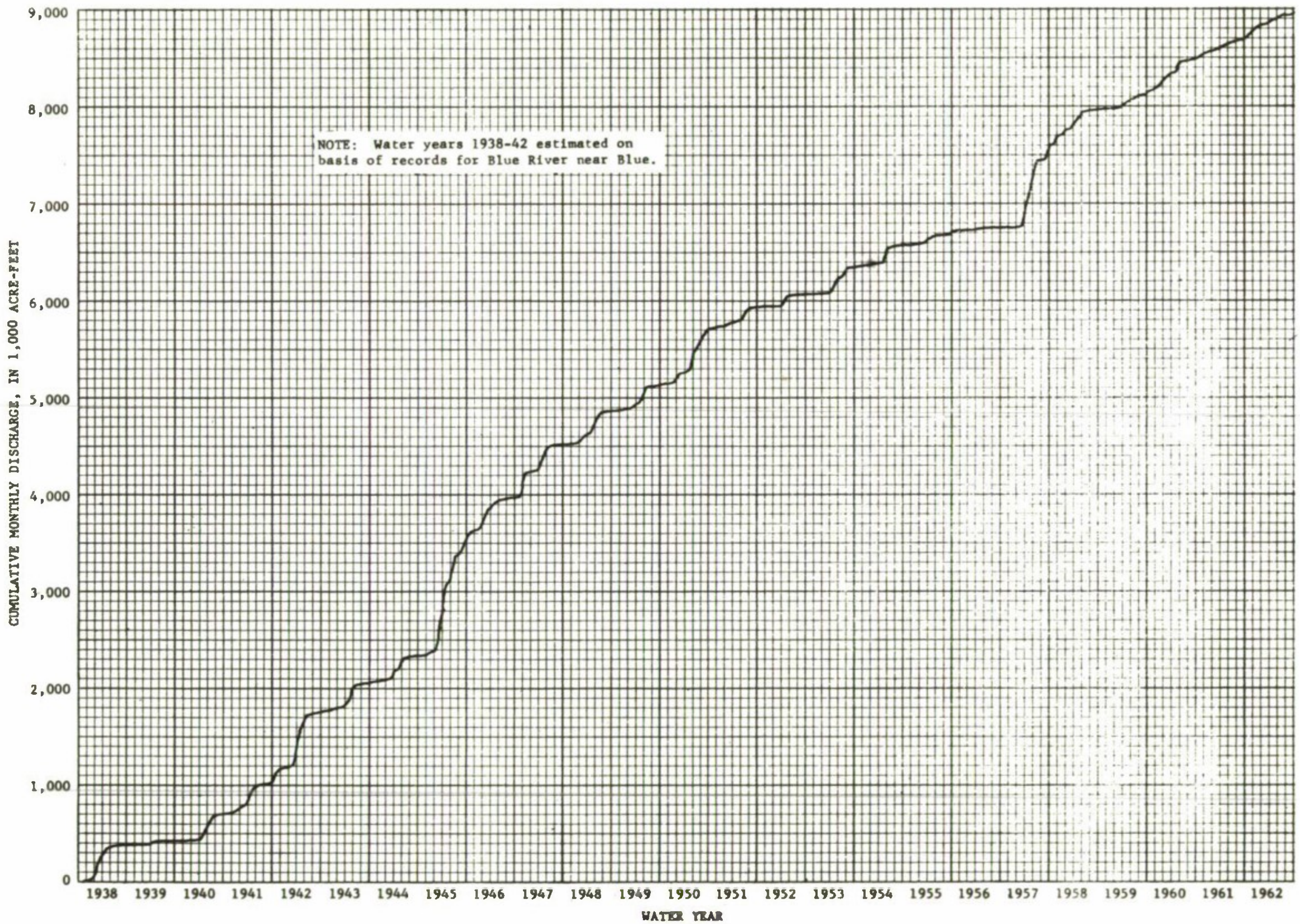


Figure 28.--Example of simple mass curve.

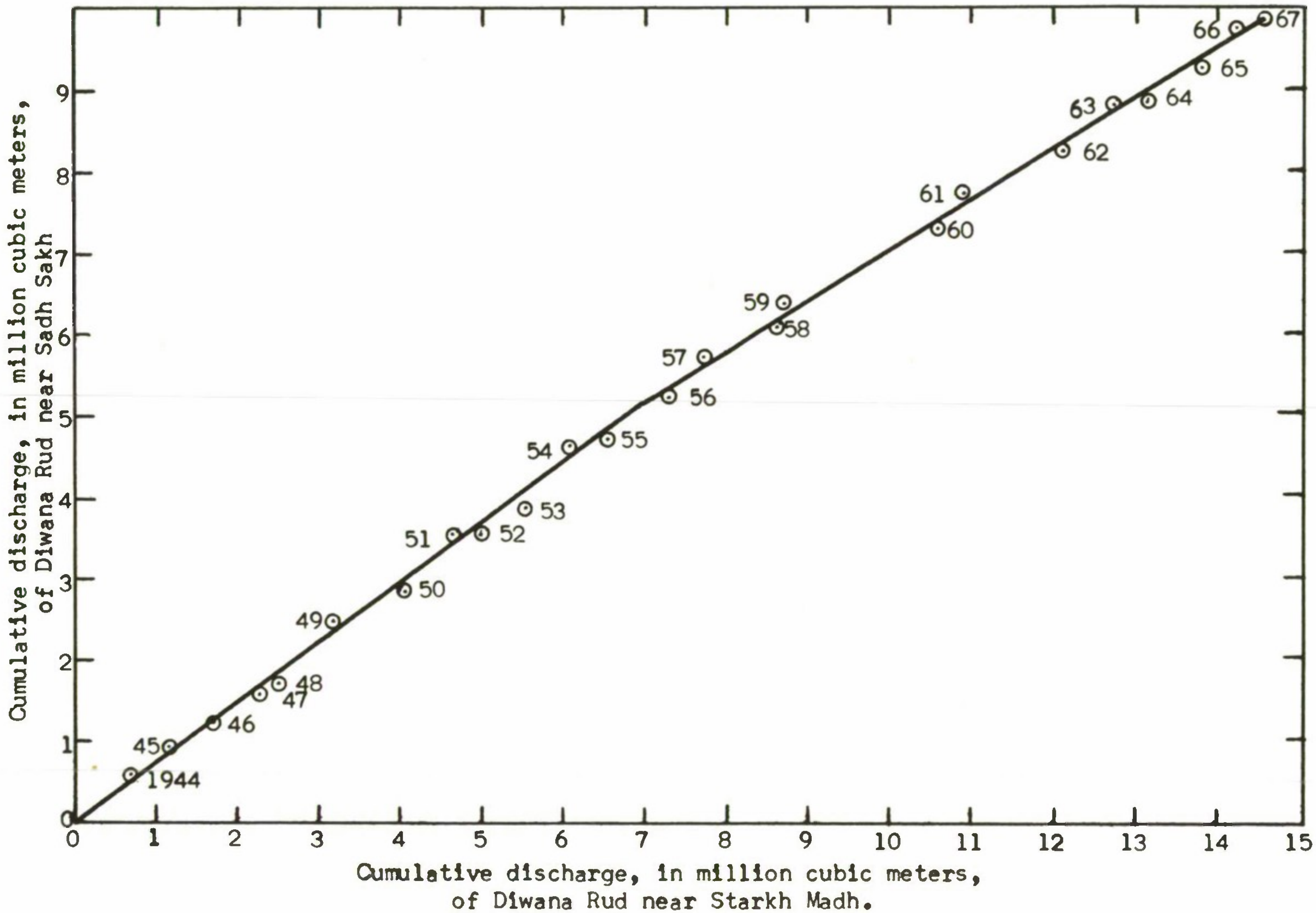


Figure 29.--Example of double mass curve.

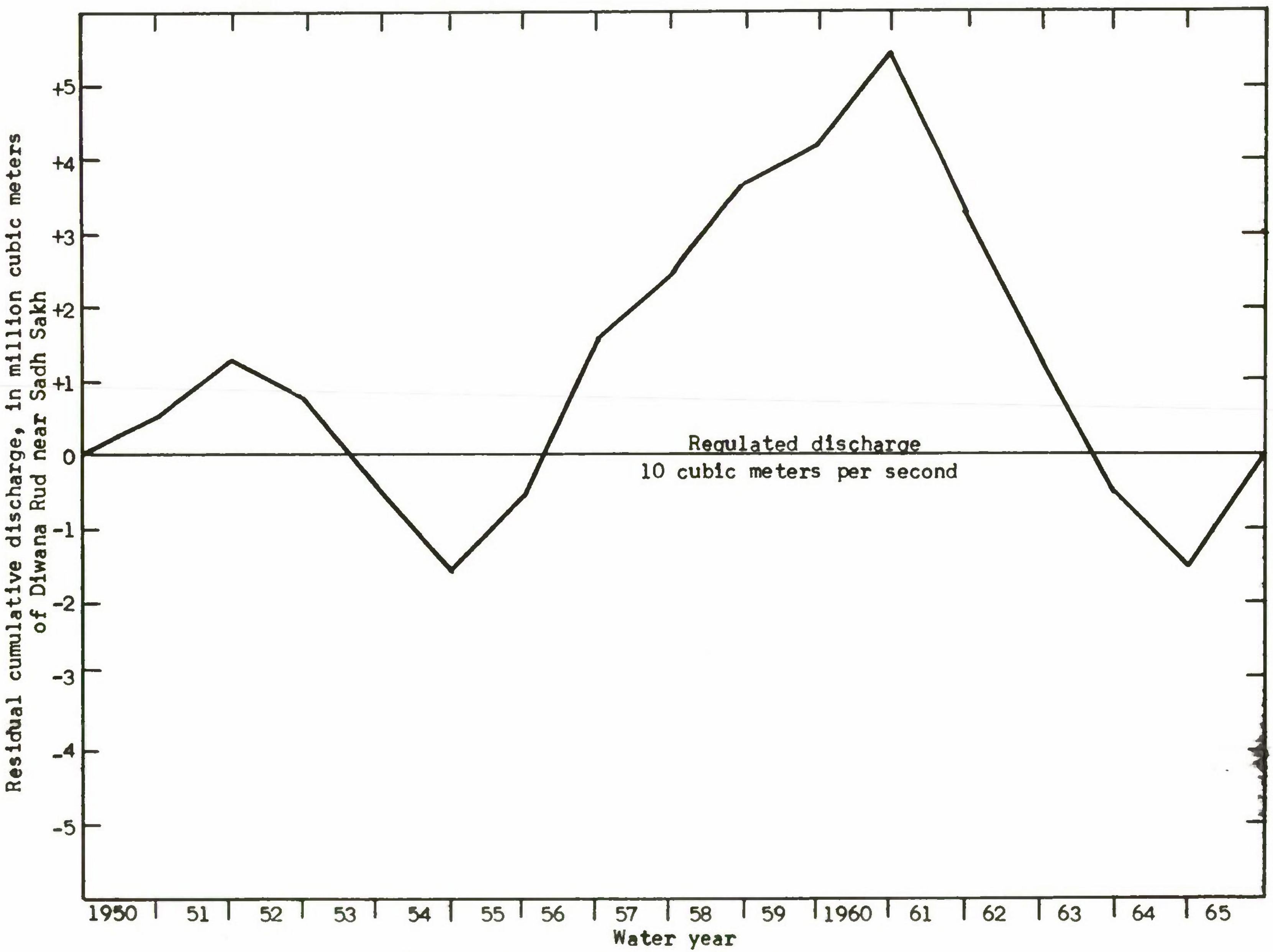


Figure 30.--Example of residual mass curve.

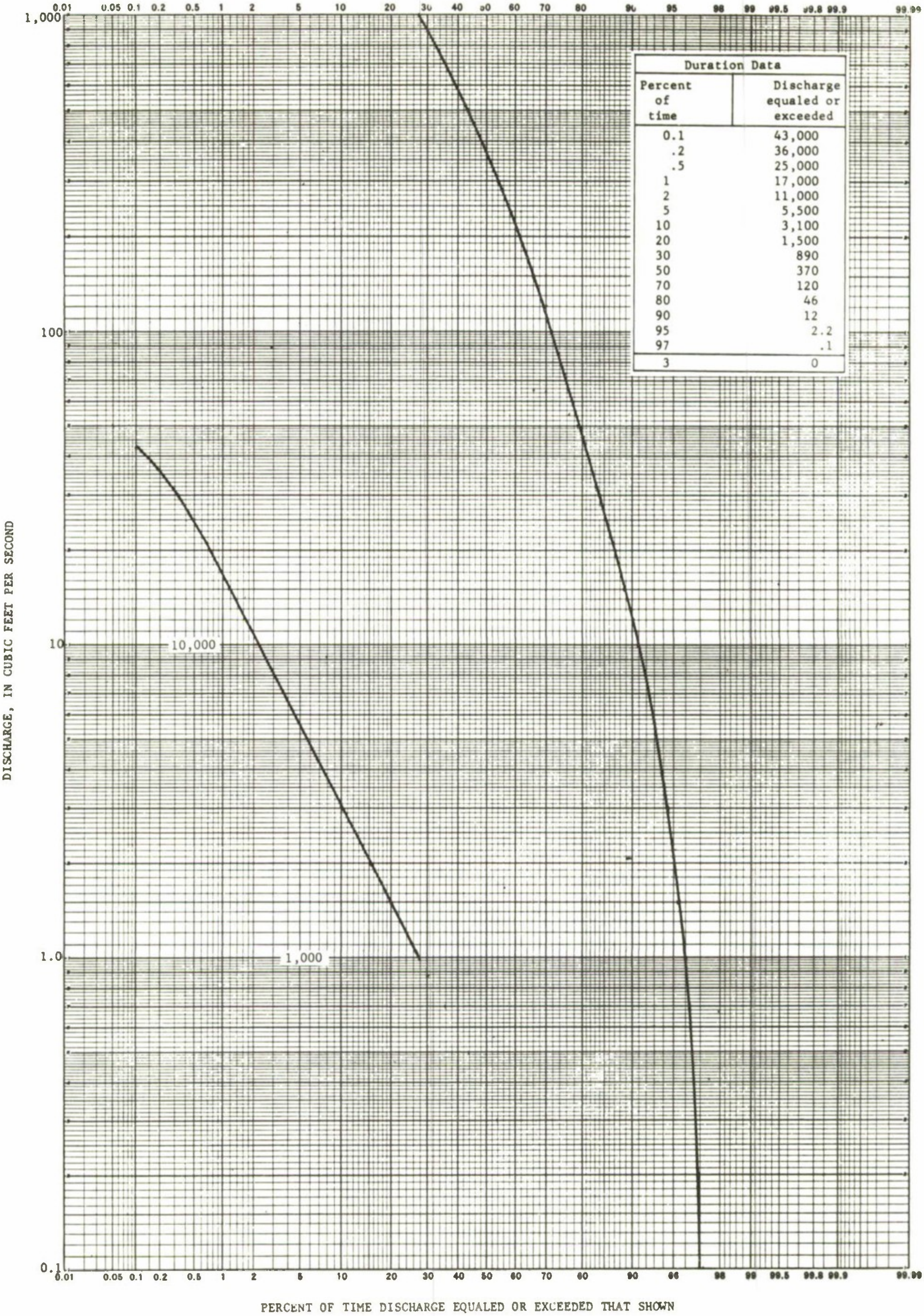
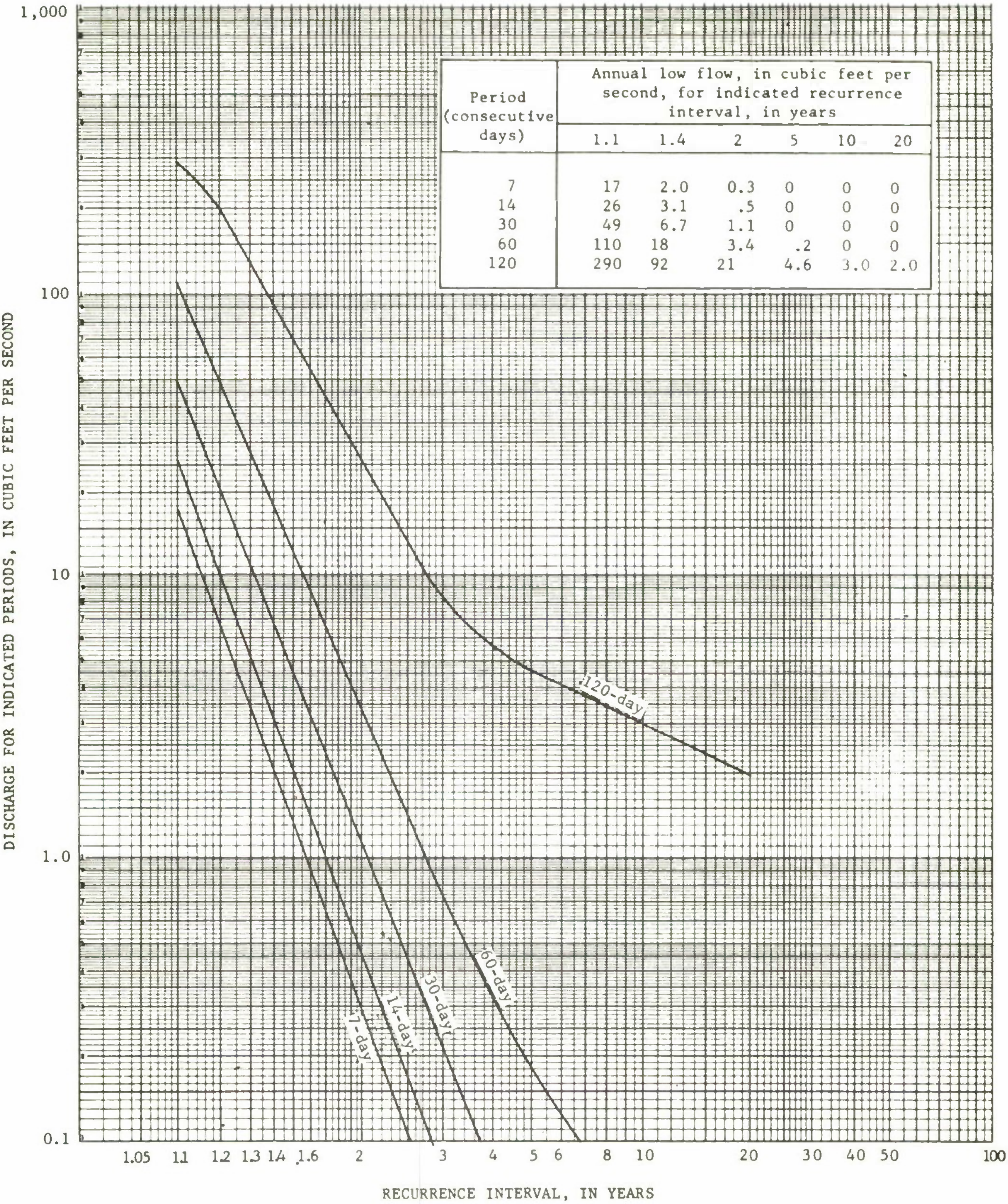


Figure 31.--Example of duration curve.



Period (consecutive days)	Annual low flow, in cubic feet per second, for indicated recurrence interval, in years					
	1.1	1.4	2	5	10	20
7	17	2.0	0.3	0	0	0
14	26	3.1	.5	0	0	0
30	49	6.7	1.1	0	0	0
60	110	18	3.4	.2	0	0
120	290	92	21	4.6	3.0	2.0

Figure 32.--Example of frequency curve.

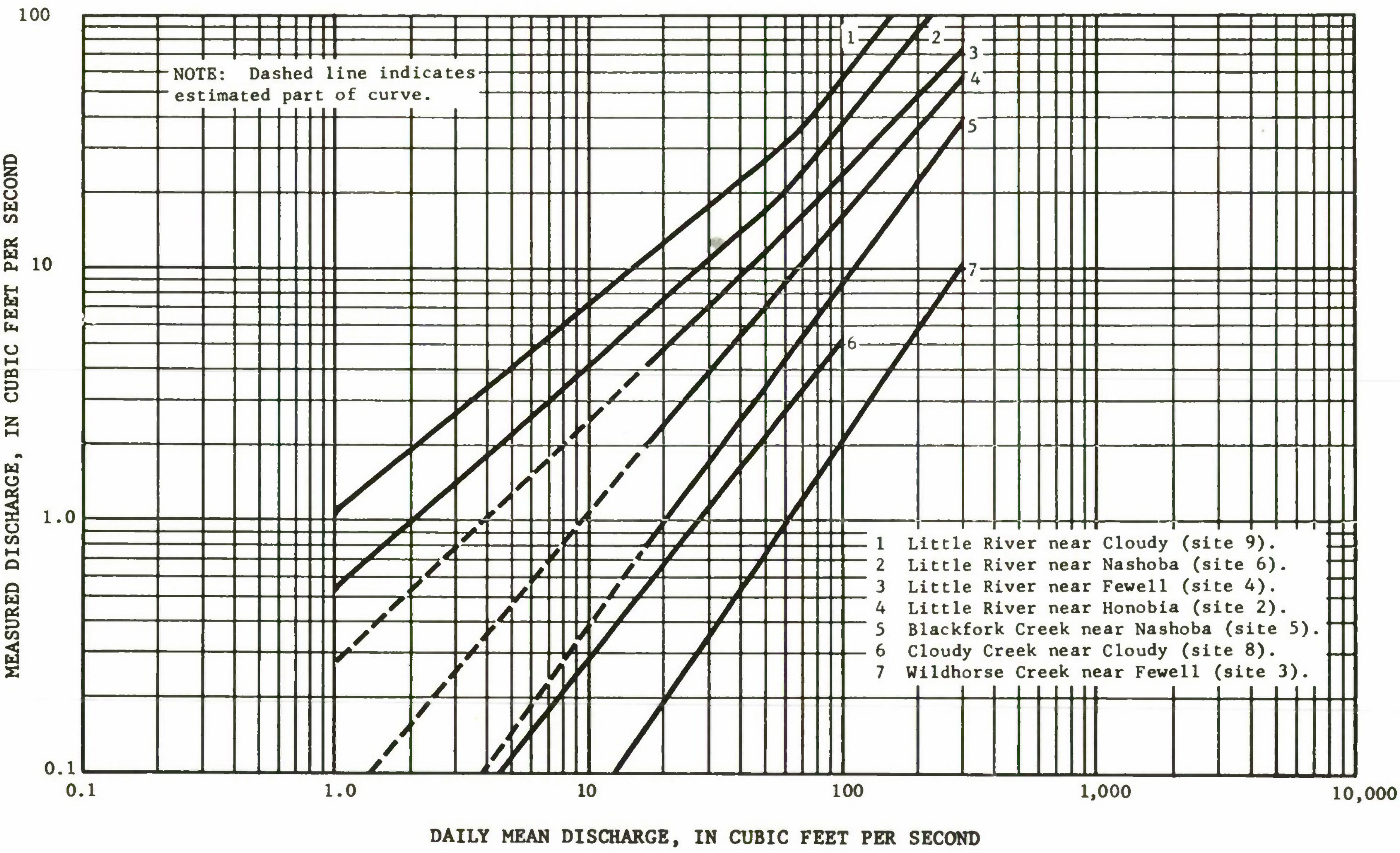


Figure 33.--Example of a simple curve of relation.

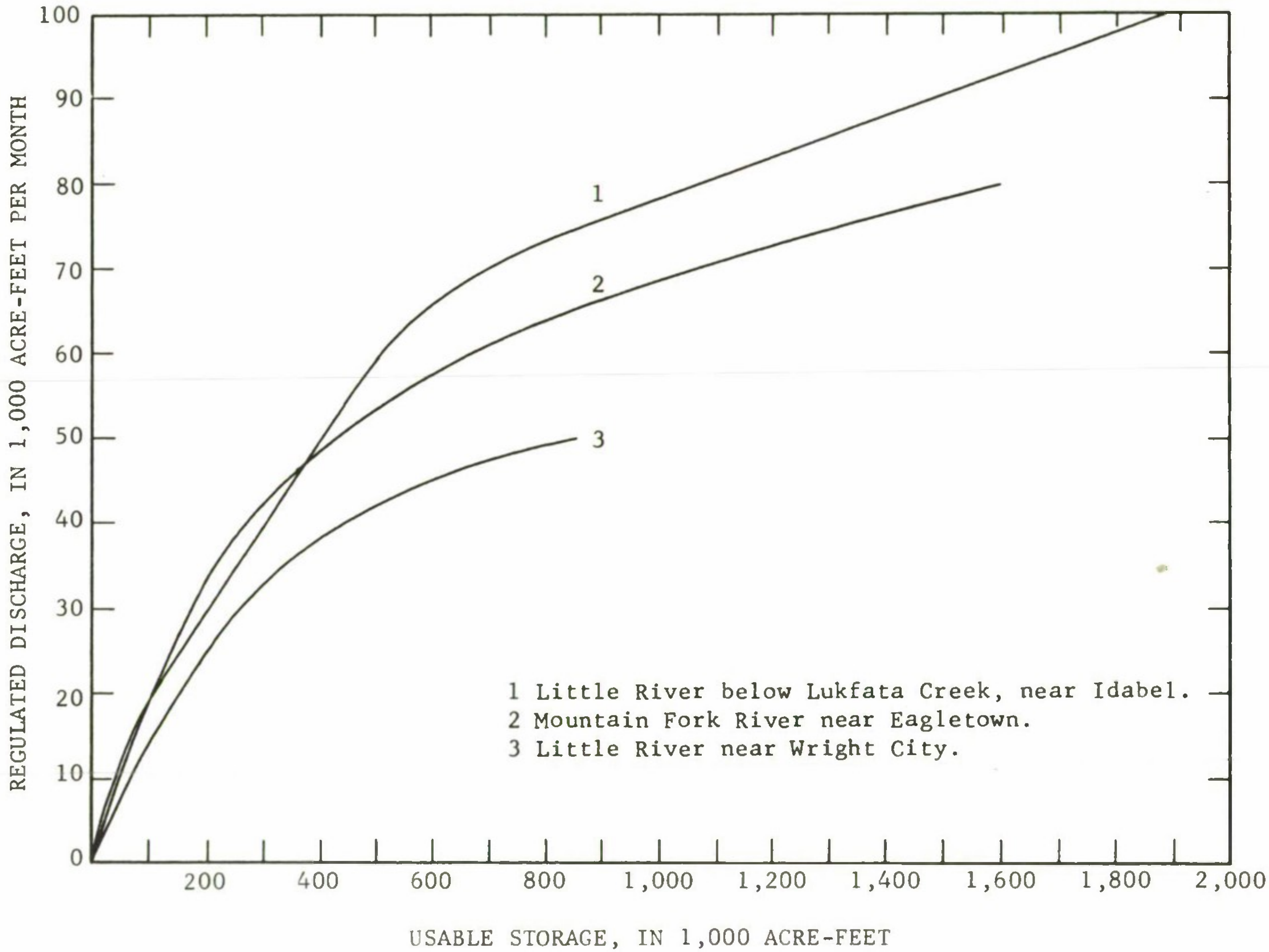


Figure 34.--Example of a simple curve of relation.

† CLASS YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
																NUMBER OF DAYS IN CLASS		
1925							8		16	15	11	6	16	9	10	19	29	24
1930	26						19		2	3	9	14	13	4	9	13	4	8
1931											1	1	9	6	19	45	37	32
1932										3	6	12	6	7	12	10	7	9
1933										3	4	1	10	13	13	22	32	32
1934	54						2		3	3	4	4	3	6	5	16	6	18
1935											4	6	17	19	18	32	10	9
1936	38				4		4		2	4	6	5	9	5	11	18	10	19
1937										4	3	2	12	4	7	11	8	12
1938									2	6	4	15	16	5	10	6	8	13
1939	12	5	3	4	5	5	13	3	6	3	5	11	12	7	20	18	12	13
1940		2					1	2	2	1	1	3	4	4	17	20	14	15
1941													9	12	29	31	9	17
1942												2	4	3	2	17	13	13
1943	38	1	1	2	2	2	8	2	2	5	3	6	12	7	15	12	3	8
1944	25									4	10	10	13	11	13	13	15	10
1945		4	8	2	2	4	5	1	3	7	2					2	13	12
1946							1	8	3	12	3	3	12	6	15	13	6	12
1947			1	3	1	3	6	1	2	19	5	17	10	5	8	4	10	10
1948										3	4	5	5	9	11	35	14	15
1949										13	14	3	4		2	16	24	32
1950																3	2	15
1951												3	4	2	4	11	16	35
1952	27	1	3	2		6	6	3	2	9	3	6	12	13	6	17	7	6
1953	48		1							1	4	10	10	13	18	22	7	6
1954	55	3	1	5	5	4	14	4	10	15	4	16	7	4	5	17	3	7
1955												3	10	10	23	16	7	12
1956		9	6	4	2	3	4	4	8	17	9	10	14	6	15	52	24	24
1957	21	5	5	3							1	5	9	6	9	23	16	13
1958															2	14	18	19
1959															1	21	15	23
1960															2	12	7	19
1961																8	25	32

† CLASS YEAR	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	RECORDS TOTAL CFS-DAYS
	NUMBER OF DAYS IN CLASS																	
1925	33	28	54	38	11	9	14	5	2	4	2			1	1			151635.0
1930	16	21	17	31	24	32	35	18	14	10	9	7	3	1	2	1		458978.0
1931	31	13	27	44	17	27	12	10	10	10	8	2	3	1				285267.0
1932	15	9	44	23	64	25	14	9	42	12	4	27	3	1		2		622373.0
1933	17	14	16	23	16	42	32	17	21	18	8	5	2	3	1			454302.0
1934	27	11	35	42	33	27	27	16	11	6	1	3	2					242935.0
1935	7	3	5	19	24	49	38	22	26	19	8	14	5	2	5	4		804860.0
1936	26	41	41	31	14	19	20	17	12	5	2	2			1			217947.0
1937	24	19	12	32	34	44	42	30	23	16	10	9	5	2				528638.0
1938	17	14	29	37	29	33	38	23	24	9	8	7	3	3	2	2	2	677025.5
1939	15	16	24	26	19	27	25	14	13	14	3	5	2	2	2	1		400045.0
1940	25	25	44	53	38	30	17	5	13	11	7	4	6	2				366691.8
1941	20	15	13	28	50	33	25	17	25	15	9	7	1					381489.0
1942	16	17	21	45	43	48	44	24	20	17	9	2	1	1	3			470159.4
1943	22	27	32	53	21	19	27	11	11	7	2	1	2		1			234489.0
1944	13	7	14	18	21	50	35	19	19	16	13	9	5	2		1		534929.0
1945	17	8	34	54	29	32	22	16	21	24	14	11	3	4	4	6	1	952014.2
1946	6	11	17	41	42	38	29	11	23	19	15	5	6	5	2		1	666370.8
1947	11	19	27	36	49	32	22	7	14	21	8	3	8			2	1	542101.6
1948	20	14	10	51	34	33	34	11	17	21	8	3	4	2	2	1		509381.1
1949	26	15	24	31	27	31	30	20	15	14	10	3	3	2	3	2	1	585737.1
1950	25	22	29	56	26	30	34	23	27	27	16	10	10	2	3	5		925974.0
1951	44	23	41	48	36	23	17	14	10	14	8	6	2	4				399419.0
1952	7	7	18	21	34	23	35	29	31	13	8	5	1		3	2		520450.8
1953	9	5	14	20	14	27	31	28	26	23	7	8	5	4	3	1		645935.1
1954	16	15	30	32	19	17	11	9	13	15	4	1	2	1	1			259078.2
1955	23	12	22	43	31	37	42	20	22	15	10	5		2				405415.4
1956	22	12	19	24	16	14	12	11	9	9		5	1	1				210724.1
1957	12	5	23	27	28	23	19	21	22	30	10	12	10	1	6			729485.3
1958	23	21	30	50	31	24	28	34	36	16	10	2	5	1		1		508419.0
1959	25	26	48	59	42	33	19	14	18	11	5	2	2		1			326537.0
1960	27	24	33	31	29	37	61	20	21	20	9	4	7	1		2		597418.0
1961	34	18	38	56	27	22	34	11	19	18	12	5	2	2	1	1		488537.0

Summary: Total days in class interval and cumulative frequency of flows.

CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT
	.0	344	12053	100.0	09	3.0	150	11395	94.5	18	100	671	8593	71.3	27	3000	499	1204	10.0
1	.1	30	11709	97.2	10	5.0	120	11245	93.3	19	150	537	7922	65.7	28	5000	257	705	5.8
2	.2	29	11679	96.9	11	7.0	179	11125	92.3	20	200	885	7385	61.3	29	7000	194	448	3.7
3	.3	25	11650	96.7	12	10.0	262	10946	90.8	21	300	1223	6500	53.9	30	10000	114	254	2.1
4	.5	21	11625	96.4	13	15.0	196	10684	88.6	22	500	972	5277	43.8	31	15000	53	140	1.2
5	.7	27	11604	96.3	14	20.0	331	10488	87.0	23	700	990	4305	35.7	32	20000	47	87	.7
6	1.0	91	11577	96.1	15	30.0	589	10157	84.3	24	1000	925	3315	27.5	33	30000	34	40	.3
7	1.5	28	11486	95.3	16	50.0	431	9568	79.4	25	1500	556	2390	19.8	34	50000	6	6	.1
8	2.0	63	11458	95.1	17	70.0	544	9137	75.8	26	2000	630	1834	15.2	35	70000	0	0	.0

† Discharges within class interval equal or exceed that shown in summary but are less than that shown in following interval.

Figure 35.--Example of a table of duration data.

HIGHEST MEAN DISCHARGE FOR FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	150	183	274
1925	21600.0	13700.0	6460.0	3450.0	1790.0	1360.0	1010.0	934.0	847.0	751.0	548.0
1930	32900.0	17900.0	13300.0	9700.0	6550.0	3380.0	2590.0	2370.0	2420.0	2290.0	1670.0
1931	17900.0	9870.0	5450.0	4090.0	3240.0	2370.0	1840.0	1550.0	1390.0	1270.0	998.0
1932	35900.0	21900.0	11800.0	9840.0	8220.0	6000.0	4720.0	3760.0	3220.0	2760.0	2240.0
1933	26900.0	16000.0	10300.0	6880.0	5130.0	3440.0	3150.0	2800.0	2650.0	2260.0	1600.0
1934	13200.0	10700.0	6380.0	4790.0	3030.0	2090.0	1550.0	1480.0	1330.0	1180.0	856.0
1935	46300.0	30200.0	16600.0	10600.0	7960.0	6360.0	5100.0	4730.0	4160.0	3890.0	2910.0
1936	27900.0	13200.0	6920.0	4050.0	2520.0	2030.0	1440.0	1140.0	1110.0	960.0	759.0
1937	17500.0	10600.0	8860.0	6660.0	5260.0	3650.0	2710.0	2500.0	2420.0	2200.0	1730.0
1938	60200.0	39500.0	21500.0	11700.0	10100.0	5750.0	5400.0	4400.0	3760.0	3320.0	2460.0
1939	41800.0	24900.0	12200.0	8770.0	5940.0	4730.0	3670.0	3010.0	2550.0	2130.0	1460.0
1940	17000.0	13000.0	9350.0	6710.0	4260.0	3260.0	2750.0	2300.0	2060.0	1780.0	1310.0
1941	12200.0	7800.0	6590.0	4720.0	3100.0	2220.0	1860.0	1730.0	1810.0	1760.0	1380.0
1942	28500.0	18000.0	9460.0	4890.0	3760.0	2830.0	2490.0	2120.0	2050.0	2050.0	1660.0
1943	20300.0	11900.0	6270.0	3420.0	2140.0	1620.0	1320.0	1270.0	1170.0	1100.0	854.0
1944	32500.0	23300.0	13000.0	6860.0	5260.0	4150.0	4210.0	3650.0	3110.0	2760.0	1940.0
1945	62100.0	44800.0	22200.0	16400.0	10900.0	8820.0	7000.0	6080.0	5030.0	4420.0	3220.0
1946	50100.0	26600.0	13100.0	9330.0	5910.0	4360.0	3600.0	3730.0	3780.0	3210.0	2420.0
1947	50300.0	22600.0	11800.0	6390.0	4780.0	3370.0	2500.0	1940.0	1810.0	2050.0	1680.0
1948	49400.0	23500.0	11800.0	6210.0	5440.0	3370.0	3370.0	2970.0	2590.0	2500.0	1830.0
1949	58200.0	40000.0	22000.0	12500.0	7310.0	4770.0	4100.0	3780.0	3400.0	2980.0	2120.0
1950	45000.0	29800.0	14300.0	11700.0	7810.0	6830.0	5170.0	4170.0	4170.0	3650.0	3100.0
1951	19500.0	16200.0	11400.0	6700.0	4240.0	2660.0	2280.0	1880.0	2250.0	1970.0	1400.0
1952	40800.0	27200.0	13900.0	11800.0	7320.0	4680.0	3530.0	3070.0	2760.0	2650.0	1900.0
1953	41200.0	21700.0	13100.0	9450.0	6960.0	5330.0	4430.0	3840.0	3260.0	3060.0	2350.0
1954	21600.0	14500.0	8410.0	4770.0	3090.0	2070.0	1690.0	1890.0	1620.0	1380.0	933.0
1955	19300.0	12300.0	7740.0	4420.0	3010.0	2400.0	2150.0	1920.0	1740.0	1630.0	1430.0
1956	19000.0	11200.0	6320.0	4160.0	3750.0	2280.0	1700.0	1570.0	1270.0	1050.0	767.0
1957	27900.0	23500.0	18800.0	12500.0	8390.0	6630.0	5950.0	4720.0	4410.0	3730.0	2590.0
1958	36500.0	22900.0	12300.0	7980.0	5160.0	4260.0	3350.0	2890.0	2500.0	2340.0	1790.0

LOWEST MEAN DISCHARGE FOR FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR BEGINNING APRIL 1

YEAR	1	3	7	15	30	60	90	120	150	183	274
1924	1.0	1.3	1.6	1.9	3.9	7.3	10.4	9.5	16.1	35.4	186.0
1930	.0	.0	.0	.0	.1	1.7	5.0	17.8	53.8	117.0	496.0
1931	14.0	14.0	14.6	17.1	34.8	99.1	151.0	265.0	326.0	336.0	638.0
1932	3.0	3.3	3.9	4.5	9.5	14.9	19.0	38.7	63.1	529.0	805.0
1933	9.0	9.7	11.7	18.3	46.8	67.5	129.0	244.0	352.0	358.0	507.0
1934	.0	.0	.0	.0	.0	.2	6.4	54.6	103.0	94.6	518.0
1935	5.0	5.0	6.1	9.0	12.2	19.0	47.9	98.4	411.0	718.0	658.0
1936	.0	.0	.0	.0	.0	1.2	57.0	54.7	125.0	239.0	561.0
1937	3.0	3.7	4.4	7.5	12.3	51.1	277.0	507.0	553.0	680.0	994.0
1938	.0	.0	.0	.0	.3	2.7	5.7	13.0	27.2	53.0	279.0
1939	.1	.1	.3	.7	3.4	16.9	16.9	37.8	56.1	86.8	196.0
1940	10.0	10.0	11.6	14.5	19.7	31.1	160.0	405.0	688.0	883.0	1140.0
1941	14.0	14.7	15.7	20.5	35.3	48.9	99.2	241.0	446.0	559.0	953.0
1942	7.0	9.1	10.9	14.3	22.0	113.0	141.0	126.0	183.0	325.0	499.0
1943	.0	.0	.0	.0	.0	.0	.6	7.8	51.3	89.2	366.0
1944	.1	.1	.1	.2	.8	6.7	23.2	22.1	94.3	192.0	651.0
1945	47.0	49.3	55.9	87.2	143.0	363.0	344.0	1140.0	1090.0	975.0	1530.0
1946	1.4	1.5	1.5	2.0	3.0	5.4	9.6	19.9	67.8	630.0	874.0
1947	.2	.3	.5	.9	3.2	23.1	77.0	671.0	638.0	724.0	1360.0
1948	3.0	3.1	3.1	3.6	4.6	8.7	28.2	42.4	56.2	62.1	428.0
1949	28.0	28.7	30.9	35.7	71.8	86.4	194.0	264.0	341.0	479.0	1090.0
1950	62.0	63.7	65.4	69.9	80.8	118.0	162.0	272.0	578.0	821.0	1110.0
1951	8.6	9.3	10.7	19.4	34.1	114.0	141.0	391.0	692.0	897.0	1200.0
1952	.0	.0	.0	.0	.0	.0	.1	1.6	4.5	51.6	513.0
1953	.4	.4	.5	.8	1.6	4.5	11.6	33.1	91.5	439.0	715.0
1954	.0	.0	.0	.0	.0	.0	1.4	18.0	253.0	579.0	695.0
1955	8.4	9.1	11.3	17.4	35.3	62.5	54.7	143.0	184.0	166.0	272.0
1956	.0	.0	.0	.0	.0	2.2	2.0	3.8	10.0	41.5	290.0
1957	6.1	7.2	8.3	11.4	27.2	49.4	77.9	214.0	316.0	570.0	817.0
1958	25.0	27.7	32.1	52.9	103.0	162.0	206.0	254.0	364.0	391.0	664.0

Figure 36.--Example of flow summary tables.

(200)
WR3wsw
appendix 15

GAGE HEIGHT IN FEET .... FEET

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

9-279-G (REV. 11-65)

RATING CURVE FOR..............................

DISCHARGE IN CUBIC FEET PER SECOND

GPO 916-178

Curve approved by:

.... Office Engineer.

.... District Engineer.

Date........................

Water year														
Meas. Nos.														
Meas. not plotted														
Max. G. H.														
Min. G. H.														
Plotted by														
Checked by														

Sta. No..............

9-279-L Jan 54 UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) | RATING CURVE FOR ______________

* GPO : 1959 OF—493896

GAGE HEIGHT (FT)

DISCHARGE (CFS)

(200)
WR 3 wsw
appendix 15

9-192b (December 1949) (200) WR3wscw appendix 15

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of .... River / Creek

At / Near .... for the Year Ending September 30, 19....

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY—WATER RESOURCES DIVISION

Drainage area .... Square miles. Type of gage .... Observer ....

Tables dated .... Periods of use .... Use half-tenths between ....

File Number: Washington .... District ....

Use hundredths below and tenths above these limits.

Max. Disch. .... Sec.-ft. at .... on .... (G. H. .... ft.). Max. G. H. .... ft. at .... on ....

Min. Disch. .... Sec.-ft. on .... (G. H. .... ft.). Min. G. H. .... ft. on ....

Day	October		November		December		January		February		March		April		May		June		July		August		September	
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								
11																								
12																								
13																								
14																								
15																								
16																								
17																								
18																								
19																								
20																								
21																								
22																								
23																								
24																								
25																								
26																								
27																								
28																								
29																								
30																								
31																								
Second-foot-days																								
Mean																								
Adjusted mean																								
Second-feet per square mile																								
Runoff in inches																								
Runoff in acre-feet																								
Maximum																								
Minimum																								

Calendar Year ....

Remarks

Period ....

Year ....

Computations	First	Second	Third	Fourth
Quarter				
Computed				
Checked				
Date				

Discharge	First	Second	Third	Fourth
Quarter				
Applied				
Checked				
Date				

Gage height	First	Second	Third	Fourth
Quarter				
Copied				
Checked				
Date				

U. S. GOVERNMENT PRINTING OFFICE: 1962 O—752-454 908-531

9-279
(Rev. 6-63)

(000)
WR3wsw appendix 15

UNITED STATES DEPARTMENT OF THE INTERIOR—GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

RATING CURVE FOR ____________________ Sta. No. __________

GAGE HEIGHT IN FEET

DISCHARGE IN CUBIC FEET PER SECOND

Year,												
Meas. Nos.,												
Max. G. H.,												
Min. G. H.,												
Plotted by												
Checked by												

Curve approved by:

__________ Office Engineer.

__________ District Engineer.

Date __________

U.S. GOVERNMENT PRINTING OFFICE 16—58146-8

9-211c
(Rev. June 61)

(200)
WR3wsw
appendix 15

UNITED STATES DEPARTMENT OF THE INTERIOR—GEOLOGICAL SURVEY—WATER RESOURCES DIVISION

STA. No. ______

Daily discharge, in second-feet, of ______, *for the year ending September 30, 19* ______

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

MEAN												
ACRE-FEET												

YEAR OR PERIOD MEAN ______

ACRE-FEET ______

(200)
WR3wsw
appendix 15

9-197
(May 1949)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

File No. Washington ______
Field ______

Description Prepared ______
(Date)

by ______

Description of Gaging Station on ______ River / Creek

At / Near ______ State of ______

Prepare description in accordance with outline on back of Form 9-277. Plot cross section to scale. Use Form 9-213A for sketch and cross section. Initial and date all sheets.

16—58616-1 U. S. GOVERNMENT PRINTING OFFICE

9-210-a
(Rev. 5-62)

(200)
WR3wsw

UNITED STATES DEPARTMENT OF THE INTERIOR

Rating table for appendix L5 GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) Sta. No. ____________

____ *Dated* ____________, *19* ____

from ____________ *to* ____________; *from* ____________ *to* ____________

from ____________ *to* ____________; *from* ____________ *to* ____________

Gage height	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	Difference
Feet	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*	*Cfs*
.0											
.1											
.2											
.3											
.4											
.5											
.6											
.7											
.8											
.9											
.0											
.1											
.2											
.3											
.4											
.5											
.6											
.7											
.8											
.9											
.0											
.1											
.2											
.3											
.4											
.5											
.6											
.7											
.8											
.9											

Computed by ____________ /____/19____; *Checked by* ____________ /____/19____ *Remarks* ____________

9-258A
(June 1952)

(200)
WR3wsw
appendix 15

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Drainage Area Tabulation for __________ State __________

From __________ to __________

QUADRANGLE	SECTION DIVISION	AREA—IN SQUARE MILES				REMARKS
		ADJUSTED	TRIBUTARY	INTERVENING	ABOVE POINT	

Tabulated: __________ Date: __________ Checked: __________ Date: __________ Page: __________

U. S. GOVERNMENT PRINTING OFFICE 16—67400-1

GPO 944639

9-230

(200)
WR3 wsw
appendix 15

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

File No. { Washington ....
District ....

U.S. GOVERNMENT PRINTING OFFICE: 1965—O-763-759

(200)

9-258
(Rev. 3-60)

WR3wsw
appendix 15

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

NW	N	NE
W	C	E
SW	S	SE

DRAINAGE AREA COMPUTATION—MAP: ____________________

Latitude ____________ to ____________ Scale ____________
Longitude ____________ to ____________ Contour interval ____ feet.
Date of map ____________ Horizontal datum ____________

DIVISION SECTION	PLANIMETER			AREA—SQUARE MILES		DESCRIPTION AND REMARKS
	READINGS	DIFFERENCE	MEAN	COMPUTED	ADJUSTED	

Computed: ____________ Date: ____________ Checked: ____________ Date: ____________ Page: ____________

U.S. GOVERNMENT PRINTING OFFICE 16—67321-2

9-220 c
(Oct. 1951)

(200)
WR3wsw
appendix 15

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Sheet ______ of ______ Sheets

Monthly and annual discharge, in ______________, of ____________________ River at/near ______________________________
[Drainage area, ________ square miles]

16—26489-6 U.S. GOVERNMENT PRINTING OFFICE

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual	

(200)
WR3wsw
appendix 15

9-207
(Rev. 1-65)

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

Station No. ....

Discharge measurements of ...., during the year ending Sept. 30, 19....

No.	Date	Made by—	Width	Area	Mean velocity	Gage height	Discharge	Rating ______		Method	Number meas. sections	Gage height change	Time	Meas. rated			REMARKS
								Shift adj.	Percent diff.								
			Feet	*Sq ft*	*Fps*	*Feet*	*Cfs*	*Feet*				*Feet*	*Hr*				

Copied by.................... Computed by.................... Checked by....................

U.S. GOVERNMENT PRINTING OFFICE : 1965 OF—761-053
917-893

9-284 (Rev. 11-61)

(2005)
WR3WSW
appendix 15

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

HYDROGRAPH FOR..............................

Sta. No. ....

October	November	December	January	February	March	April	May	June	July	August	September
5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30	5 10 15 20 25 30

Plotted by.............. Checked by.............. Date..................

* U.S. GOVERNMENT PRINTING OFFICE : 1961 O—618795